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An Outbreak of FOOD POISONING

due to *Salmonella bovis morbificans* (Basenau)
in which the vehicle of infection
was meat pies

Report by

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PREFACE

by the Chief Medical Officer

To the Rt. Hon. IAIN MACLEOD, M.P.,
MINISTER OF HEALTH

SIR,

The whole concept of this report is eminently practical. An outbreak of food poisoning of unusual size, extent and severity involving 28 local authorities, occurred in north and west Lancashire in June, 1953. The organism responsible—*Salmonella bovis morbificans*—is itself one of the less frequently encountered causes of food poisoning. It was appreciated from the outset that meat pies had been the means of disseminating the infection but the mode of infection of the pies was by no means so readily apparent. The several medical officers of health concerned in the investigations were assisted by Mr. R. V. Blamire a veterinary officer of the Ministry of Food, and by a medical officer from this Department, and the fullest use was made of the resources of the Group Laboratory at Preston Royal Infirmary and of the services of Dr. A. A. Miller, the pathologist in charge of this laboratory.

In the first part of the report Dr. Miller and Dr. Nicol (of this Department) recount the circumstances of the outbreak in some detail and give the reasons which had led to the belief that the sources of infection must have lain in some part of the meat used in the preparation of the pies. It was not possible to recover the organism from the small remaining portion of the meat, but serological tests provided some slight but inconclusive evidence that a particular herd from which some of the meat had been derived might have been infected with *Salmonella bovis morbificans*. These investigations, which were arranged through the good offices of Mr. Blamire, strengthened the hypothesis but still left to be explained the circumstances in which the infecting organisms survived the processes of baking.

In the second part of the report Dr. Miller and Mr. F. Ramsden, Chief Technician at Preston Group Laboratory, describe the series of ingenious controlled experiments which they devised and undertook to determine the effects of graduated baking times and temperatures on the survival of *Salmonellae bovis morbificans* and *typhimurium* in the smaller meat pies.

It has perhaps been too uncritically assumed that bakery products are sterile on leaving the oven and that where illness has been caused by pies or by flour confectionery the infection has been introduced subsequently. It is more than fifty years since Delépine and Howarth published their report on an outbreak of food poisoning in Derby and gave reasons for their conclusion that the source of infection had been meat contaminated by offal while in the raw state, supporting their argument by the results of certain

experiments which Delépine carried out to ascertain the internal temperatures of pies during and immediately after baking. Since that time little has been heard of the subject and the original work of Delépine has been largely forgotten. Indeed, it was the apparent absence of any reliable information on the possibility of bacteria surviving exposure to the accepted standard times and temperatures employed by bakeries which led to the present elaborate studies. Dr. Miller and Mr. Ramsden have demonstrated that the traditional methods of baking provide only a small margin of safety, and that in the presence of pre-existing infection in meat a slight departure from normal baking time or temperature may permit the survival of sufficient pathogenic organisms to multiply later to the detriment of the consumer.

Their report bridges the gap between bacteriologist and baker. The proposals in the recommendations set out at the end of the report are not onerous, and their acceptance in practice would go far to ensure the safety of this popular article of diet. I would add, that though the report is being published by the Ministry of Health, the opinions expressed and the suggestions made are those of the authors themselves.

I have the honour to be,

Sir,

Your obedient Servant,

JOHN A CHARLES.

Ministry of Health.
May 1955.

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PART I

An outbreak of food poisoning due to *Salm. bovis morbificans* (Basenau) in which the vehicle of infection was meat pies

by
A. A. Miller, C. G. M. Nicol and F. Ramsden.

Introduction

SALMONELLA infections in West Lancashire are usually associated with endemic and sporadic cases of gastro-enteritis and with occasional outbreaks during the warm months of the year. In the summer of 1953, an explosive outbreak of considerable magnitude and severity was superimposed on the endemic level. This outbreak lasted for well over a week and affected more than a thousand persons. Of these 32 were admitted to hospital and 5 died there. The vehicle of infection was meat pies produced by one bakery.

The causative organism of the outbreak, *Salm. bovis morbificans* had not been isolated during the previous six years in the large and fairly heavily populated area served by the Preston Group laboratory although some twenty other species of salmonellae had been found, certain of them being infrequently encountered in this country. Only once in the whole records of this laboratory had *Salm. bovis morbificans* been isolated. This was from a fatal case of a man aged 51 years. The organism was presumed to have been consumed in infected shell-fish when the patient was on holiday at the sea-side during the summer of 1940.

Not only is the organism rare in this district but it is uncommon in England and Wales as a whole.

We are indebted to Dr. Joan Taylor of the Salmonella Reference Laboratory for the table printed on page 28 showing the total number of strains of salmonella submitted to that laboratory during the past 30 years from which it is seen that between 1923 and 1952 *Salm. bovis morbificans* amounted to 0·9 per cent of the total number of salmonella strains received. In no case was the organism associated with an outbreak of any size.

Infections due to Salm. bovis morbificans

A salmonella species considered to be of animal origin, *Salm. bovis morbificans* was first described by Basenau in 1893, who isolated it at Amsterdam from a diseased cow which had aborted and developed mastitis with subsequent septicaemia. Since then, the organism has been recovered from human and animal sonrces in many parts of the world.

In Germany there have been sporadic cases and small outbreaks. Pierret *et al.* (1951) mention a small outbreak in France. In England, it has been isolated from the mesenteric lymph nodes of pigs, (M.R.C. 1947 a), and from spray-dried eggs, (M.R.C. 1947 b): from pork sausages and pork pie flour

in a food factory in Northern Ireland, (P.H.L.S., W.S.53/27), and from rodents in Nottingham (Ludlam, 1954), and from a pig in Bradford (P.H.L.S. W.S. 54/45). Reports of human infection in England and Wales were made by Sladden and Scott (1927) and Haines and Wilson (M.R.C. 1947 c). From South Africa, there is one report of an outbreak due to infected pork (Henning and Greenfield 1937) and from India one case reported by Hayes and Freeman (1945). American workers both in the U.S.A. and in other parts of the world have found this organism only infrequently. A triple human salmonella infection in which one of the species was *Salm. bovis morbificans* was reported by Bornstein *et al.* (1941). In another report, Bornstein (1943) found only one culture of the organism out of some 500 strains from human beings, the one being from a case of septicaemia. Edwards and Bruner (1943) found none of this type in 3,090 cultures of animal and human origin. Among the 3,000 infections reported from the New York Salmonella Centre, (Seligmann *et al.* 1946), there were eleven cases; seven were gastro-enteritis of which one was fatal; two were symptomless excreters and two contacts of known cases. The same authors also reported a small outbreak affecting six infants in a hospital ward. Angrist and Mollov (1946) described a small outbreak involving six premature infants; three of the infections were mild and the others asymptomatic: the writers regarded the organism as being distinctly rare. Among the 3,016 cultures identified by Edwards *et al.* (1948) six were *Salm. bovis morbificans*, three being from human cases of gastro-enteritis and two from symptomless excreters; the last strain was from a rodent. Hormaeche *et al.* (1945) did not isolate this salmonella among 537 strains from children in Uruguay. In a large series of 1,007 salmonella cultures from 892 individuals in the Mediterranean area reported by Brunner and Joyce (1947) it was recovered from two individuals, one of whom was a carrier. Lindberg and Bayliss (1946) working in the Pacific area did not find it among 202 strains they examined in one year (1944–5). In Australia, *Salm. bovis morbificans* appears to be widely distributed and is found in a variety of domestic animals as well as man. It was isolated from sheep and pigs by Stewart (1940 a, b), from sheep's kidneys by Atkinson *et al.* (1944), from a foal and from the faeces of a cow by Albiston (1947) (quoted by Mackerras and Mackerras, 1949, a), and from a duck by Simmons (Mackerras and Mackerras, 1949, a). Atkinson *et al.* (1944, 1947) reported typical cases of gastro-enteritis due to this salmonella in many parts of Australia, both adults and children being affected. Most of the illnesses appear to have been mild. More recently Mackerras and Mackerras (1949 a) reported a major epidemic of gastro-enteritis in which there were several fatalities among infants and young children in the Brisbane area.

Present Outbreak

Before 1953 the only recorded outbreaks in England and Wales due to this particular strain were one of 14 cases in Birmingham in 1948 and one of 4 cases at Oxford in 1949. The outbreak reported here was of major proportions, there being over a thousand notified cases as well as many more which were not formally notified. It appears to have been one of the largest outbreaks of salmonella food poisoning on record.

The cause of the infection was the consumption of contaminated meat pies and its extent was coincident with the area of distribution of the product.

This area included a large part of the County of Lancashire, extending from the Lancaster district in the North to the Wigan district in the South. The county boroughs of Blackpool and Preston were severely affected but Blackburn and Wigan had only a few cases each. The map (Fig. 1) shows the distribution of notified cases and Table 1 the number of cases notified in each county borough and administrative county district.

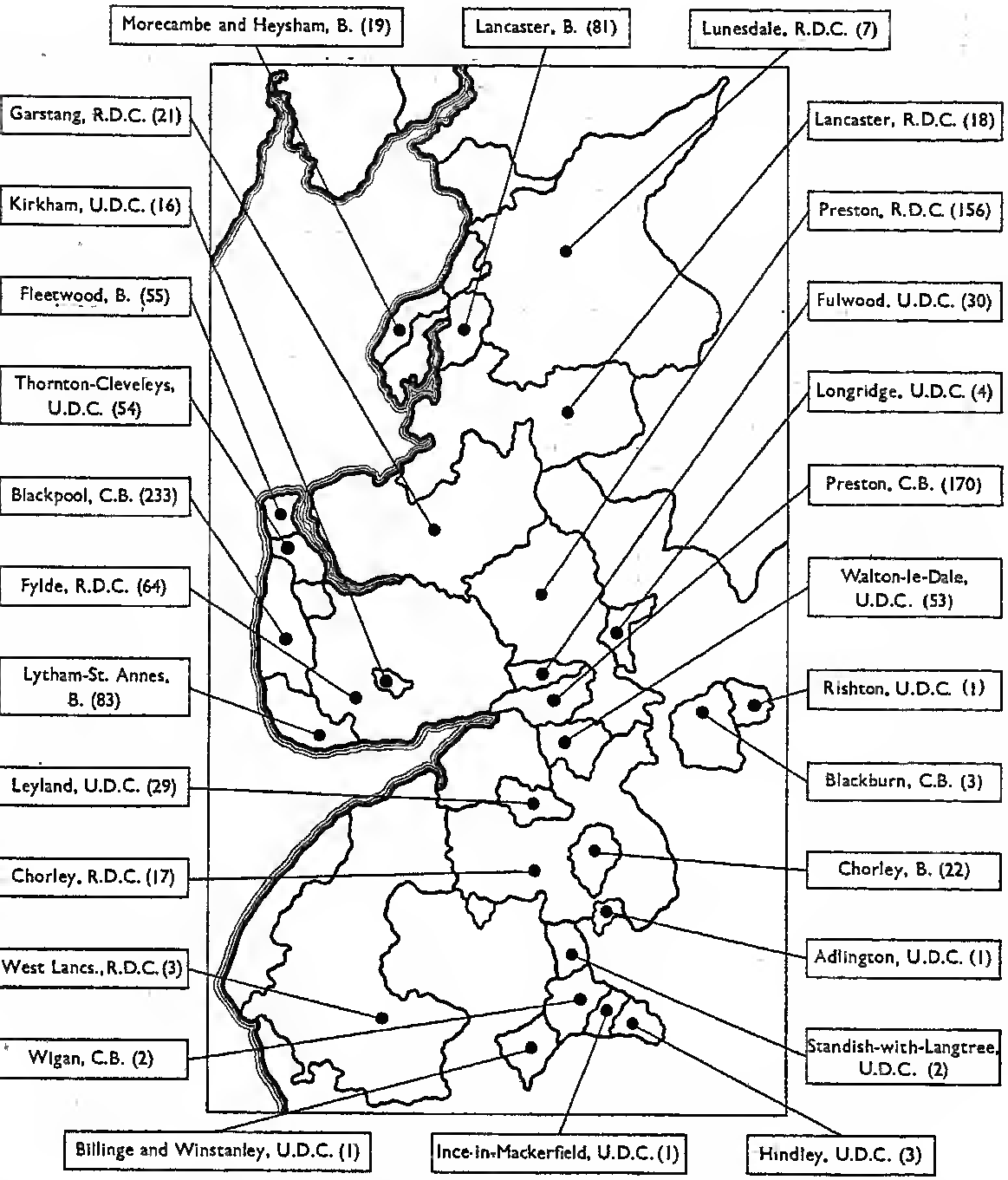

FIG. 1. Map of West Lancashire showing the affected local authority areas and (in parentheses) the number of cases ascertained in each.

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TABLE 1

Notified cases of Food poisoning in Lancashire, June 1953

Districts	Number of Cases	Admissions to Hospital	Deaths
County districts (24)	741	24	5
Preston County Borough	170	5	—
Blackpool County Borough	233	3	—
Blackburn County Borough	3	—	—
Wigan County Borough	2	—	—
	1,149	32	5

Breakdown of County Districts

Districts	No. of cases	Districts	No. of cases
Adlington Urban Dist.	1	Morecambe & Heysham Borough	19
Billinge and Winstanley Urban Dist.	1	Rishton Urban Dist.	1
Chorley Borough	22	Standish with Langtree Urban Dist.	2
Fleetwood Borough	55	Thornton Cleveleys Urban Dist. ...	54
Fulwood Urban Dist.	30	Walton-le-Dale Urban Dist. ...	53
Hindley Urban Dist.	3	Chorley Rural Dist.	17
Ince-in-Makerfield Urban Dist. ...	1	Fylde Rural Dist.	64
Kirkham Urban Dist.	16	Garstang Rural Dist.	21
Lancaster Borough	81	Lancaster Rural Dist.	18
Leyland Urban Dist.	29	Lunesdale Rural Dist.	7
Longridge Urban Dist.	4	Preston Rural Dist....	156
Lytham St. Annes Borough ...	83	West Lancs. Rural Dist.	3
			741

The first cases appeared on the 10th June and were followed by increasing numbers on the 11th, 12th, 13th and 14th June, and by still more during the following week, when many notifications were received from all the towns and districts affected. Persons of all ages were infected, from babes-in-arms to persons of over 70 years, but the majority were adults as would be expected from meat pies being the vehicle of infection. Most of the victims were taken ill in their own homes, the pies being purchased from shops and consumed at home. There were, however, two notable peak epidemic periods in which large numbers were infected at their work and recreation. On the 11th June, about eighty persons became ill after eating meat pies for lunch at a large works canteen. Five hundred and forty 4 oz. meat pies of satisfactory appearance had been delivered to the canteen on the 11th June, having been baked on the previous day. Most of the affected workers had eaten one or two cold pies, but in some instances the pies had been warmed before consumption. The onset of symptoms was between 6 and 30 hours later. Many of the workers bought pies and took them home for family consumption. One man took eight pies to his home in Wigan; two were eaten by his brother who became violently ill with diarrhoea and vomiting; one was consumed by another member of the family without ill effects and the remaining five were submitted to the laboratory for examination.

A similar incident took place at a tennis club party on Saturday, 13th June, when over 112 persons out of a party of 350 had gastro-enteritis after a small meal which had included meat pies. Many of the victims were very ill and one died. Four hundred and eighty 4 oz. pies had been delivered to the club, 388 on the 12th June, having been baked on the 11th, and 96 on the 13th June, having been baked on the 12th. Both deliveries were exposed to the high atmospheric temperatures prevailing at the time. Approximately 200 of the 484 pies were wholly or partly consumed. Some of those affected had eaten about a quarter or one half of a 4 oz. pie, and had thrown away the rest because its taste was unpleasant, although its appearance was normal. This question of peculiar taste in some of the pies is discussed at greater length in the section devoted to consideration of meat supplies. There is no history of any person having eaten more than one pie. From the histories available there would appear to be no relation between the weight of meat pie eaten and either the length of the incubation period or the severity of the illness; the patient who suffered the longest illness ate only one bite from the crust. In this group the illnesses followed after periods of six to fifty-six hours, the majority occurring between 12 and 30 hours after the meal. The meat pies responsible for the outbreaks at the works canteen and the tennis club party were traced to a single bakery, where further pie making was voluntarily stopped as soon as the circumstances became known.

The contaminated products were manufactured mainly on three days, the 10th, 11th, and probably the 12th of June and nearly all the cases of infection were traced to pies made on those days. The numbers of pies produced, and the area of distribution which included most towns and districts within a radius of forty miles of the bakery, are shown below—

Date	*No. of pies baked*	*Distribution*	
10th June ...	... 3,000 ...	... Leyland (540)	The remainder were widely distributed over the Lancaster area, the Fylde and districts south of Preston.
11th June ...	... 3,000 ...	... Fulwood (388)	
12th June ...	... 350 ...	... Fulwood (96)	

There were, however, some sixteen of the early cases, and one fatal case in the Lancaster area, which could only be assumed to have some source of infection other than meat pies.

The Causative Organism

The first faecal specimens from victims of the outbreak were received by the laboratory on the night of Saturday 13th June but unfortunately the history of the infection was at that time unknown. On Monday the 15th June when non-lactose-fermenting colonies had been isolated, the correct information about the magnitude and the explosive nature of the outbreak had become available. The first colonies isolated were subcultured to peptone water, nutrient agar slopes and urea medium (Christensen, 1946) and some eight hours later, in the early evening, the various sugars were inoculated and preliminary slide agglutinations were performed on agar slope cultures. As a result of these tests the organism appeared to be a salmonella (specific phase) which agglutinated fairly well with *Salm. paratyphi C.* 0 (6, 7,) serum

and readily with *Salm. newport* 0 (6, 8), and *Salm. bovis morbificans* H(r), sera. The several strains examined at this time were closely similar in all respects and the organism was provisionally typed as *Salm. bovis morbificans*. On the following morning the fermentation and other reactions confirmed the earlier findings.

Four strains were immediately submitted to the Salmonella Reference Laboratory of the Central Public Health Laboratory at Colindale Avenue, London, which reported that the organisms had the antigenic structure 6, 8, r ⟷ 1,5 and were therefore *Salm. bovis morbificans*.

At the beginning of the investigation the *in vitro* sensitivity of twenty-four strains of the organism to aureomycin and chloramphenicol was determined with a view to assisting practitioners in the choice of an appropriate antibiotic for treatment. The results of these tests are shown in the following table:—

Antibiotic Sensitivity tests of 24 strains of Salm. bovis morbificans (Dried disc method Fairbrother and Martyn (1951)).

Aureomycin (500 micrograms per ml.)	Chloramphenicol (2000 micrograms per ml.)	Number of Strains
Sensitive	Highly sensitive	1
Moderately sensitive	Highly sensitive	2
Slightly sensitive	Highly sensitive	8
Resistant	Highly sensitive	13
	Total No.	24

Bacteriology

The exceptional demands made on the laboratory during the investigation of this outbreak led to the evolution of a method of rapid screening by which operative procedures were greatly reduced without sacrifice of accuracy. The method is described on page 28.

All but a few of the strains examined by this technique were identified as *Salm. bovis morbificans*: two of the remainder were found to be *Salm. minnesota* and these two had been recovered from patients who had eaten meat pies: *Salm. bovis morbificans* was *never* isolated from these patients. Again, there were several patients who had a double salmonella infection, some with *Salm. typhi murium* and one with a possible new type related to *Salm. mississippi*: its antigenic structure, determined by Dr. Joan Taylor, was 13, 23, b⟷1,6.

During the investigation a large number of whole pies and unconsumed portions, and other foods were received by the laboratory. All the partially consumed pies together with a proportion of the whole ones were examined. Of the 34 cultured 24 were found to be heavily infected throughout with *Salm. bovis morbificans*. Quantitative estimations were not carried out because the unbroken pies as well as the fragmented portions had been exposed to high atmospheric temperatures for a period of two or three days. The other foods examined included meat paste sandwiches which had been

served at the tennis club party. Where intact specimens were cultured, salmonellae were not isolated but in the case of a sandwich which had been thrown into a dust-bin with other food from the party *Salm. bovis morbificans* was isolated. It is possible that the infection in this case had taken place in the bin. None of the meat paste was available for examination.

As the scope of the investigation widened, an amazing variety of other specimens were submitted. These included swabs from the working surfaces in butchers' shops, from knives and cutting machines, also flies, cockroaches, and faecal specimens from rodents, cats and dogs. In no instance was *Salm. bovis morbificans* isolated except in the case of a dog which had eaten scraps of a meat pie.

TABLE 2

Analysis of faecal examinations for Salm. bovis morbificans in 1,123 patients with gastro-enteritis of which 563 were positive

Pie Consumed	Organism in Faeces	Age Group	Preston C.B.	Preston R.D.	Lytham B.	West Lancs. R.D.	Longridge U.D.	Kirkham U.D.	Garstang R.D.	Leyland U.D.	Fylde R.D.	Fulwood U.D.	Chorley B.	Walton-le-Dale U.D.
Yes ...	Positive	0— 5	5	2	—	—	—	1	—	2	1	—	—	—
		6—15	4	3	—	—	—	3	—	2	1	—	—	—
		16—21	10	3	—	—	—	—	—	1	—	—	—	1
		Over 21	97	53	—	—	—	11	6	17	7	21	4	7
	Negative	0— 5	—	—	—	—	—	—	—	—	—	—	—	—
		6—15	—	—	—	—	—	—	—	—	—	—	—	—
		16—21	8	—	—	—	—	—	—	—	—	—	—	—
		Over 21	14	3	8	—	—	1	2	—	—	1	—	—
No	Positive Primary	0— 5	2	—	—	—	—	—	—	—	—	—	—	—
		6—15	1	2	—	—	—	—	—	—	—	1	—	—
		16—21	1	—	—	—	—	—	—	—	—	—	—	—
		Over 21	7	1	—	—	—	—	—	—	—	—	1	—
	Positive Contacts	0— 5	4	—	—	—	—	—	—	—	—	—	—	—
		6—15	—	3	—	—	—	1	—	—	—	—	—	—
		16—21	—	—	—	—	—	—	—	—	—	—	—	1
		Over 21	7	3	1	—	—	—	—	1	—	1	2	1
	Negative	0— 5	50	—	—	—	—	—	—	—	—	—	—	—
		6—15	11	3	—	—	—	—	—	2	—	—	—	—
		16—21	—	—	—	—	—	1	—	—	—	—	—	—
		Over 21	54	12	6	—	—	—	2	17	2	1	1	—
Not Known	Positive	0— 5	9	6	—	—	—	—	1	—	2	1	—	2
		6—15	13	6	—	—	1	2	1	—	3	1	—	1
		16—21	3	3	—	—	—	—	1	—	2	—	3	1
		Over 21	49	52	8	—	1	4	13	7	14	2	8	40
	Negative	0— 5	33	4	—	1	—	—	1	—	—	—	3	1
		6—15	36	—	5	—	—	—	3	1	—	3	2	—
		16—21	9	1	—	—	—	—	1	—	—	2	—	4
		Over 21	148	24	18	2	1	1	13	14	4	5	6	16

The Results of Bacteriological Examinations

Table 2 is an analysis of the 1,123 people from whom faecal specimens were examined by this laboratory *in connection with the outbreak.* It shows the age groups affected, the administrative area in which the patient lived and the history of eating meat pies, where this was known. The section marked "positive primary" includes all cases stated not to have eaten meat pies and who were infected in the very early days of the outbreak. It is considered unlikely that they were cases of secondary infection. The possibility of other foods, such as minced meat and pork, being responsible for their illness cannot be excluded (vide section on clinical findings) but, as samples of these foods were never available for examination, direct evidence could not be found. The size of the large group in the table labelled "not known" regarding the history of eating pies, is due to lack of information on the laboratory request forms. This omission of detail is no reflection on the staffs of health departments who were responsible for collecting the specimens: they were most helpful throughout the epidemic but circumstances made the collection of complete details impracticable.

Clinical features of forty cases of gastro-enteritis due to Salm. bovis morbificans

Clinical history. Most of the patients were treated in their homes by medical practitioners, a large proportion of the illnesses being of mild or moderate severity. The clinical picture was usually that of gastro-enteritis but the severity and persistence varied greatly, all grades from transient abdominal pain with some diarrhoea to fulminant attacks with prostration and dehydration being seen. Owing to the numbers affected, the wide distribution of the outbreak and the consequent pressure of work on the staffs of health departments, accurate clinical information was often difficult to obtain. However, through the help and co-operation of medical practitioners and the staff of the Deepdale Isolation Hospital, it was found possible to study a small group of forty patients, some of whom were sufficiently ill to require admission to hospital. This small group was a fairly representative sample of the many who suffered in the outbreak.

In all the cases in this group, save four, the vehicle of infection had been pies manufactured by one bakery. The four patients in question stated that their illnesses followed the eating of minced meat, corned beef, pork and boiled ham. No unconsumed portions of these foods were available for examination so that closer investigation was not possible.

The incubation period varied between six and forty-eight hours: in about 40 per cent it was less than twenty-four hours and in only six instances was the time less than eight hours. In one fatal case it was seven hours. From the histories available there seems to have been no relation between the number of pies eaten and the length of the incubation period, or the severity of the illness.

All the patients in this group, which included children and adults, complained of diarrhoea and abdominal pain: the majority complained of vomiting, nausea and headache. Some patients stated that the diarrhoea, in one or two instances with bright red blood, was almost continuous at the

onset and then became less severe, averaging about 12 evacuations a day for the first few days. Generalised muscular pain and blurred vision were less common. One patient suffered from influenza-like pains for about twenty-four hours before the onset of diarrhoea. One adult showed symptoms of severe toxaemia with vomiting and abdominal cramp, had meningeal symptoms and was semi-comatose for about a week. The majority of the patients showed accompanying pyrexia with temperatures between 101–102°F. An infant of ten months and a young child of fourteen months each showed temperatures up to 105–106°F., both of them being extremely ill.

Therapy. During the acute infection almost all the patients were treated with chloramphenicol in large doses for about a week. After 4–6 days of this treatment they all showed lower or normal temperatures, the fall having taken place by lysis, and the majority experienced considerable relief of symptoms, probably the result of treatment. On discontinuing the antibiotic one young child had a mild relapse with high temperature, but further administration of chloramphenicol controlled the temperature and produced clinical improvement.

The average duration of the disease was two weeks, though quite a number of patients were in hospital for three to four weeks. In over 60 per cent of the cases symptoms of severe toxaemia were encountered, but none of them was suggestive of typhoid or paratyphoid fever. One case, a young woman aged 39 years, with symptoms of profound toxaemia, proved fatal after fifty-four hours duration.

Relapses. During the third week of their illnesses two patients had mild relapses from which they soon recovered. A third case, a man aged 32 years, who had recovered from a severe attack of gastro-enteritis, suffered from continued bouts of abdominal pain and diarrhoea (with positive cultures) for about five months after the acute infection. During convalescence, about six weeks after the acute illness, his serum agglutinated *Salm. bovis morbificans* H(r) to 1 : 50 and O to 1 : 125. He had received two courses of chloramphenicol presumably with relief of the toxaemic symptoms, but with no obvious effect on the continued diarrhoea and carrier state. Still another patient, a woman of 40 years, who was taken ill after the meal at the tennis club sustained a prolonged illness for more than a year. At the onset of her illness she suffered from severe toxaemia with high temperature, abdominal pain and diarrhoea from which she recovered with the aid of antibiotic therapy, but continued to experience intermittent abdominal pain and diarrhoea at about fortnightly intervals for over eleven months, while cultures from her faeces were still positive fourteen months after the acute infection. Her serum agglutinated *Salm. bovis morbificans* H(r) to 1 : 125; H(1, 5) to 1 : 250 and O to 1 : 50; fourteen months after the acute illness. During the relapses she had received several courses of chloramphenicol, streptomycin, and sulphonamides with no apparent effect on the carrier state.

Persistent carriers. After clinical cure and in spite of one or more courses of antibiotic and other therapy many patients remained carriers of *Salm. bovis morbificans.* The most persistent carriers in this investigation were five patients who were excreting the organism for periods of between three hundred and four hundred and forty days after the initial infection.

Duration of excretion of Salm. bovis morbificans in the 39 persons in this group (one had died), all of whom had been treated with chloramphenicol in heavy doses

Weeks	*Excreters yielding negative stool cultures*
0–4	10
4–8	12
8–12	6
More than 12	11
Total	39

Duration of excretion of the organism in another group of 563 persons many of whom had also been treated with chloramphenicol

In another large group of cases for which there are no clinical details the period for which the organism was excreted is shown in Table 3.

TABLE 3

Periods for which 563 patients excreted Salm. bovis morbificans

Period in weeks	Total number examined	Number showing cultural clearance	Number still excreting, and from whom further specimens were not obtained
0– 1	563	37	141
1– 2	385	92	26
2– 3	267	87	9
3– 4	171	29	12
4– 5	130	46	14
5– 6	70	12	—
6– 7	58	15	2
7– 8	41	5	2
8– 9	34	9	5
9–10	20	3	3
10–11	14	1	—
11–12	13	1	—
12–13	12	1	4
13–14	7	1	1
Over 15	5	0	5*

* Some of these patients were examined later and were found to be still excreting the organism after 28–43 weeks and one after 64 weeks.

The duration of infection is difficult to assess because in so many cases the latest specimens were still positive. This was partly due to the fact that not all health authorities requested faecal clearance after clinical cure. The exceptions were, of course, food handlers where cultural clearance was essential. Most of the patients in this group seem to have been bacteriologically clear by the fourth week but five were still carrying the organism after fifteen weeks in spite of treatment with chloramphenicol, streptomycin and sulphonamides.

In the graph (fig. 2) the cases where the last specimen was still positive are spread over the curve in accordance with the distribution of numbers where bacteriological clearance was established; this graph is therefore only an approximate representation of the data.

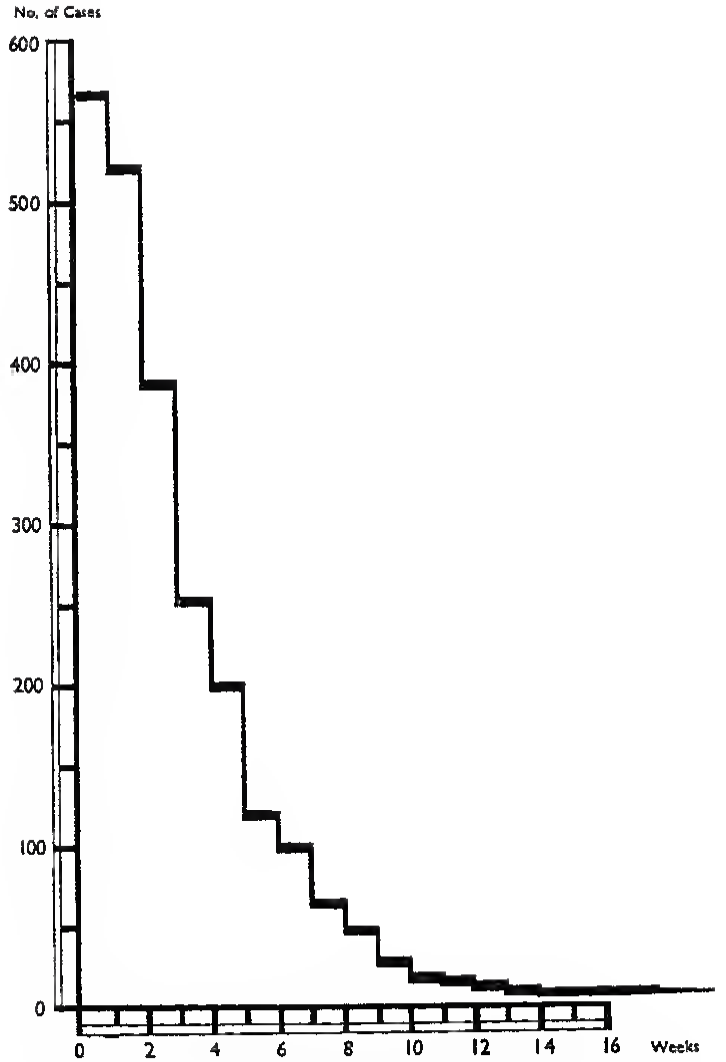

FIG. 2. Graphical representation of the periods for which a group of 563 patients excreted Salm. bovis morbificans.

Examination of samples of blood serum from forty-two patients including the group whose clinical features have been described

Owing to extreme pressure of work during the first few weeks of the outbreak no sera were examined during the acute stage of this infection, the blood serum from each of the group of forty-two patients being examined for agglutinins to *Salm. bovis morbificans* for the first time 2–3 months afterwards, and again three months or more later. All the serological tests on the initial and subsequent examination were not carried out on the one day, but the same suspensions, obtained from the Salmonella Reference Laboratory, and the same technique were employed throughout.

Although all the patients harboured the epidemic organism rather less than 70 per cent of them showed evidence of antibody production. In the positive sera the titres to H(r) and O antigens are much lower than would be expected, especially as some of the patients were carrying the organism for a very long period. Even in the patient I.T. – B(4) (Table 5) who had suffered bouts of diarrhoea for a period of over a year, and was still carrying the

organism, the serum titres to both H(r) and O were only 1 : 125. The highest titre was observed in a woman, Mrs. H.–A(6) (Table 4) whose serum agglutinated the O antigen to 1 : 500 when examined about two and a half months after her illness.

Perusal of the literature did not reveal any reported series of agglutinations to this organism with which to compare our results. In two tests by Sladden and Scott (1927) and one by Schiff and Saphra (1940) the serum titres were much higher than in our series. Low serum titres have occasionally been reported both in convalescence (Atkinson, in Mackerras and Mackerras, 1949 a) and during the acute illness (Taylor, personal communication, 1940); in a fatal case (a male adult) about a week after the commencement of his illness, Taylor found that his serum agglutinated *Salm. bovis morbificans* H(r) to 1:25; H(1,5) to 1:25; O to 1:25. Examples of agglutinin production as the consequence of infection with other salmonella species were also compared with those to *Salm. bovis morbificans*. In a few patients who had suffered from *Salm. sundsvall* infections and who were examined about two months after their illnesses, Taylor (M.R.C. 1947 d) found higher serum titres to the H antigen than those reported here but the titres to O antigen were similar.

The following groups of serological findings show special features

Group A. (Table 4.) The serum of twenty-two patients when examined on the second occasion showed a fall in the H and/or O agglutinin production which was related to *negative faecal cultures* (Table 4). In some of the cases the first serum examined showed absence of agglutinin to H(r) or O and subsequent examinations usually confirmed this finding. In five patients (cases 1, 9, 14, 15, 17) the serum showed a fall in both H(r) and O agglutinins: in the remainder of sera the fall was shown in either H(r) or O agglutinins. The actual fall in serum titre was small, usually between dilutions of 1: 125 and 1: 25 or a similar range, the period in which the fall had taken place being about three months.

TABLE 4

Examination of samples of blood serum from 22 patients. Group A.

Case	Patient	Sex	Age	Serum agglutinins to *Salm. bovis morbificans*		
				Date	H(r)	O
1	W. C. ...	F.	43	29. 9.53 20. 1.54	1 : 50 1 : 25	1 : 50 1 : 25
2	E. D. ...	F.	39	28. 7.53 3.12.53	<1 : 25 <1 : 25	1 : 125 1 : 50
3	E. G. ...	F.	50	23.11.53 13. 1.54	1 : 50 1 : 25	<1 : 25 <1 : 25
4	E. G. ...	F.	53	29. 9.53 5. 1.54	1 : 125 1 : 50	1 : 25 1 : 50
5	Mrs. H. ...	F.	51	28. 7.53 25.11.53 1. 2.54	<1 : 25 <1 : 25 <1 : 25	1 : 125 1 : 50 1 : 25

Case	Patient	Sex	Age	Serum agglutinins to *Salm. bovis morbificans*		
				Date	H(r)	O
6	Mrs. H. ...	F.	40	31. 8.53 18.12.53	<1 : 25 <1 : 25	1 : 500 1 : 125
7	S. H.	M.	47	9. 9.53 30.11.53	1 : 25 1 : 25	1 : 25 <1 : 25
8	T. J.	M.	30	16.10.53 7.12.53	1 : 25 <1 : 25	1 : 50 1 : 25
9	R. J.	M.	32	28. 7.53 25.11.53 1. 2.54 21. 9.54	1 : 50 1 : 50 1 : 25 1 : 25	1 : 250 1 : 50 1 : 25 1: 25
10	C. L.	F.	14 mths.	29. 9.53 18. 1.54	1 : 125 1 : 125	1 : 25 <1 : 25
11	E. M. ...	M.	30	24.11.53 16. 2.54	1 : 25 <1 : 25	<1 : 25 <1 : 25
12	R. N. ...	M.	8	29. 9.53 1.12.53	1 : 50 1 : 125	1 : 250 1: 125
13	I. P.	M.	68	23.11.53 13. 1.54	1 : 50 1 : 25	1 : 50 1 : 25
14	A. R. ...	F.	16	8. 9.53 30.11.53 12. 4.54	1 : 50 1 : 50 1 : 25	1 : 125 1 : 50 1 : 25
15	M. S. ...	F.	33	28. 7.53 3.12.53	1 : 125 1 : 50	1 : 250 <1 : 25
16	A. S.	M.	4	7.12.53 4. 2.54	1 : 50 <1 : 25	<1 : 25 <1 : 25
17	R. W. ...	M.	9	23.11.53 13. 1.54	1 : 50 1 : 25	1 : 50 <1 : 25
18	M. Y. ...	F.	14	8. 9.53 30.11.53	1 : 125 1 : 125	1 : 125 1 : 50
19	M. E. L. ...	F.	22	20. 9.53 18. 1.54	1 : 125 1 : 50	1 : 125 1 : 125
20	J. D.	M.	30	16.10.53 7.12.53	1 : 125 <1 : 25	<1 : 25 <1 : 25
21	M. H. ...	F.	19	23.11.53 12. 1.54	<1 : 25 <1 : 25	1 : 25 <1 : 25
22	Mrs. W. ...	F.	50	24.11.53 16. 2.54	1 : 50 1 : 25	<1 : 25 <1 : 25

Group B. (Table 5.) The serum of six patients when examined a second time showed a rise in H and O agglutinins associated with the *faecal carrier state*. In all six the rise in H(r) and O agglutinins lay between 1: 25 and 1: 75, this rise having taken place in about three months. The maintained titres for both antigens were usually 1 : 50 and 1 : 125. In the serum of one

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patient I.T. (4) who had repeated bouts of diarrhoea with positive faecal cultures for a period of over a year, the initial rise in H agglutinins was maintained, after a transient fall, for a period of about two months.

TABLE 5

Examination of samples of blood serum from six patients. Group B.

Case	Patient	Sex	Age	Serum agglutinins to *Salm. bovis morbificans*		
				Date	H(r)	O
1	J. A.	F.	6	31. 8.53 27.11.53	1 : 25 1 : 125	<1 : 25 1 : 50
2	Mr. K. ...	M.	55	20. 1.54 17. 3.54	1 : 125 1 : 125	1 : 25 1 : 50
3	E. S.	F.	60	11. 1.54 17. 3.54	1 : 50 1 : 125	1 : 50 1 : 125
4	I. T.	F.	40	30.11.53 23. 2.54 7. 4.54 10. 6.54 6. 9.54	1 : 125 1 : 50 1 : 50 1 : 125 1 : 125	1 : 50 1 : 50 1 : 50 1 : 125 1 : 50
5	P. W.... ...	F.	13	14. 9.53 2.12.53 1. 2.54 26. 4.54	1 : 125 1 : 125 1 : 125 1 : 50	1 : 50 1 : 125 1 : 50 1 : 50
6	H. R. ...	M.	32	29. 9.53 4.12.53 1. 2.54 20. 9.54	1 : 50 1 : 50 1 : 50 1 : 25	1 : 50 1 : 50 1 : 50 1 : 25

Group C. In a further group of ten patients there was *no serological confirmation of faecal infection.* The serum of these patients who had suffered moderate or severe attacks of gastro-enteritis and from whose faeces *Salm. bovis morbificans* was isolated showed no evidence of agglutinins to H and O antigens when examined, first about two to six months after their illnesses and again about three months later. A similar finding was reported by Taylor (M.R.C. 1947 e) during the serological investigation of patients who had been infected with salmonella species new to England and Wales. Taylor states "in a few instances in which blood serum was examined during convalescence agglutinins to the causal strain of salmonella were by no means always present".

Group D. In the serum of still another group of four patients, all of whom suffered sharp attacks of gastro-enteritis and from whose faeces the organism was isolated when examined three to six months after their illnesses, there was no evidence of agglutinins with the exception of one case which showed a serum titre of 1 : 50 to H(r). They were not included in Group C because only one specimen of serum from each patient had been examined.

Group E. The serum of a small control group of fourteen persons who gave no history of illness and who had not eaten meat pies was examined for agglutinins to H(r) and O antigen with negative results. One exception was a girl whose serum showed a titre of 1 : 25 to H(r). Further detailed enquiry did not reveal a history of infection nor had she received T.A.B. inoculations. Of this control group, six had been given T.A.B. and similar prophylactic inoculations in the preceding ten years but antibodies which may have developed as a result of these did not appear to have any effect on the test suspensions used.

Fatal infections due to Salm. bovis morbificans.

There were five deaths in the outbreak, one in the Fulwood urban district near Preston, and four in the Lancaster area.

Case 1. The first case, a female aged 39 years, was one of the victims of the tennis club party on the 13th June; at about 4.0 p.m. she ate a whole meat pie and seven hours later became extremely ill with abdominal pain, diarrhoea and vomiting. On Sunday the 14th she was treated with sedative with no improvement; on Monday the 15th her condition had become much worse; she complained of violent diarrhoea and vomiting accompanied by pyrexia with temperature of 101°-102°F.; she was seen by her local doctor who prescribed sulphasuccidine and later in the evening, chloramphenicol: owing to persistent vomiting it is doubtful if any of either drug was retained. During the night she became drowsy, lapsed into coma and died on the morning of the 16th, her illness having lasted fifty-four hours.

Necropsy. Examination five hours after death showed the body of a well nourished woman: greenish fluid was pouring from the rectum. On internal examination the following signs were noted; on the visceral pleurae of both lungs there were numerous petechial haemorrhages and the lung parenchyma showed acute passive congestion: on the visceral pericardium there were petechial haemorrhages of the subepicardial type. There were numerous submucous haemorrhages in the stomach: the small intestine and the colon showed patchy congestion of the serosal and the mucosal surfaces; the contents of the small and large intestines were entirely fluid and small in amount. The liver was normal in size and the cut surfaces showed congestion and areas of fatty degeneration.

A specimen of post-mortem blood showed 75 mgm urea per 100 ml: *Salm. bovis morbificans* was isolated from the stomach and the small intestinal contents. The anatomical cause of death was dehydration due to salmonella bovis morbificans gastro-enteritis.

Histology. Microscopical examination of the kidneys showed well marked albuminous exudate in the subcapsular spaces and a few foci of round cell infiltration in the cortex. Sections of the liver showed a moderate degree of fatty degeneration. In the adrenal gland there were irregular areas of cortical hyperplasia of the nodular type, separated by fibrous trabeculae; at the periphery of the nodules there was well marked lymphocytic infiltration: elsewhere in the cortex there was abundant healthy tissue for normal endocrine function.

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Case 2. A housewife aged 63 years, became ill with abdominal pain, diarrhoea and vomiting about 11.0 p.m. on the 12th June, 1953, six hours after eating a contaminated meat pie. As the symptoms persisted the family doctor was called on the third day and prescribed sulphaguanidine 1 g. 4 hourly. The diarrhoea then became less marked as the result of treatment, but the patient's condition deteriorated and eight days after the onset of symptoms she died. Chloramphenicol had not been administered.

Her husband, who had eaten one of the contaminated meat pies at the same time, also suffered an attack of food poisoning but made an uneventful recovery.

Necropsy. Examination was made forty-eight hours after death. The main findings were as follows :—the coronary arteries showed intimal plaques of atheromatous degeneration: the lungs showed hilateral hypostatic bronchopneumonia : the stomach appeared normal, the small intestine was congested throughout its whole length, the congestion being most marked in the ileum, a detailed examination of which showed engorged mucosa without ulceration. The spleen appeared normal. The cerebral arteries showed marked atheromatous degeneration but the cut surfaces of the hrain showed no significant lesion.

In the suhsequent investigation *Salm. bovis morbificans* was isolated from the splenic pulp hut not from the small and large intestines. Histological examination of the pituitary, thyroid and adrenal glands, and of the liver showed no significant changes. The anatomical cause of death was dehydration due to salmonella hovis morbificans gastro-enteritis and extra-renal uraemia.

Case 3. Male aged 72 years. Complained of shivering, ahdominal pain, sickness and diarrhoea on the 13th June, nine hours after eating a contaminated meat pie. He was treated at home with sulphaguanidine, opium and chalk mixture with no improvement. The symptoms persisted for thirteen days with increasing severity until the 26th June, when he died. His illness was characterised throughout hy symptoms of severe toxaemia : antihiotics had not heen administered.

His wife also ate a meat pie and suffered a moderately severe attack of gastro-enteritis which lasted for about a week.

Necropsy. Examination twenty hours after death showed the hody of an elderly man with evidence of marked dehydration : the lungs showed hasal congestion : the main coronary arteries were greatly thickened by atheromatous degeneration, but the myocardium did not appear fihrosed. The small intestine was congested : the spleen appeared normal : the left adrenal gland showed a small cortical haemorrhage. There was marked atheroma of the hasal arteries of the hrain and the cut surfaces showed softening of the hasal nuclei on hoth sides. *Salm. bovis morbificans* was isolated from the contents of the small and large intestines. The anatomical cause of death was dehydration due to salmonella hovis morhificans gastro-enteritis.

Histological examination of the adrenal glands showed congestion of the hlood vessels and small scattered haemorrhages in the deep layers of the cortex : there were no areas of cellular infiltration or necrosis.

Case 4. A housewife aged 48 years became suddenly ill on the 30th June, with violent diarrhoea and vomiting, six to ten hours after eating sausages. Other members of the household had eaten the same sausages without ill effects. As her symptoms persisted with increasing severity she was admitted to hospital on the 2nd July. She had symptoms of severe toxaemia and collapse, subnormal temperature and rapid pulse, dehydration and generalised tenderness of the abdomen. On the following day cultural examination of the faeces showed *Salm. bovis morbificans:* the blood serum protein was 8·4 g. per 100 ml. and the haemoglobin 104 per cent. She was treated with intravenous fluid, streptomycin and chloramphenicol but her condition deteriorated: she developed extra-renal uraemia and lapsed into coma on the 8th July. On the evening of the 9th July, shortly before her death, the blood urea rose to 124 mgm. per 100 ml. Her illness had lasted about ten days.

Necropsy. Examination twelve hours after death showed the following signs: the small intestines showed congestion of the serosal surfaces which was most marked in the terminal portion of the ileum: here the mucosa appeared engorged but there was no ulceration and no lymphoid hyperplasia. The anatomical cause of death was dehydration due to salmonella bovis morbificans gastro-enteritis.

Biochemical examination of a specimen of post-mortem blood revealed a blood urea of 142 mgm. per 100 ml., serum sodium 285 mgm. per 100 ml. and serum potassium 8·5 mgm. per 100 ml. Cultures from the small intestines and the spleen were negative for salmonellae.

Histological examination of the kidneys showed well marked albuminous exudate in the subcapsular spaces: in the medulla there were areas of focal necrosis with haemorrhages and cellular infiltration: the adrenal glands showed a moderate degree of post-necrotic scarring of unknown origin.

Case 5. Boy aged 16 years. Admitted to hospital on the 24th June, 1953, with a history of pain and tightness in the chest for the preceding three weeks with marked sweating and productive cough. There was no history of diarrhoea but his bowel action had been irregular since the commencement of the illness. He had been diagnosed as acute bronchitis and treated with penicillin, chloramphenicol and sulphaguanidine with no improvement. On admission he had tachycardia, high temperature, marked respiratory distress, rapid pulse and oedema of the ankles: he was provisionally diagnosed as suffering from myocarditis. He died fifteen hours after admission. There was no definite history of his having consumed a meat pie but the possibility cannot be excluded. In his past history five years before, he had suffered an attack of poliomyelitis which resulted in gross scoliosis of the dorsal vertebrae, with shortening of the right leg and deformity of the chest.

Necropsy. Examination four and a half hours after death revealed the body of a poorly developed adolescent with marked deformity of the dorsal spine and chest; internal examination showed the right pleural cavity to be partly obliterated by old adhesions, the left pleural cavity being normal. Both lungs showed evidence of bronchitis with pus in the bronchi and bronchioles: there was, however, no consolidation. The heart was enlarged,

all the chamhers being dilated and there were pericardial haemorrhages posteriorly at the bases: the myocardium of the ventricles appeared abnormal in places. The lower part of the small intestine showed reddening of the serosal surfaces and the mucosa was engorged with blood, otherwise the alimentary tract appeared normal. The spleen was normal. The hrain was intensely congested, all the pial vessels being distended: the cut surfaces of the brain also showed marked congestion.

Salm. bovis morbificans was isolated from the colon and spleen. Histological examination of the spleen, kidneys, heart and brain showed no significant changes. The anatomical diagnosis would appear to be salmonella bovis morhificans septicaemia: there was no other evidence of disease to account for death.

Summary of the findings in the fatal cases

During the months of June and July, 1953, in the large outbreak due to *Salm. bovis morbificans* which affected over 1,149 persons, five persons died from the infection. Their ages ranged from sixteen to seventy-two years: four of them being over thirty years. In the first three cases the vehicle of infection was contaminated meat pies and, although there is no definite history of meat pie consumption in the fifth, this possibility cannot be excluded. In the fourth case the patient attributed her illness to the consumption of sausages.

In the first four cases the onset was sudden and in three of them the incubation periods were six, seven and nine hours.

Four of the cases presented a classical picture of severe gastro-enteritis with symptoms of profound toxaemia, usually accompanied hy hyperpyrexia. One case showed a suhnormal temperature.

In the first patient, the illness was fulminant, death ensuing fifty-four hours after the commencement of symptoms. In cases two, three and four the course was more protracted, the fatal issues taking place in eight, thirteen and ten days respectively. The fifth case was entirely different from the others: his symptoms were those of infective myocarditis. However, the post-mortem findings together with the isolation of *Salm. bovis morbificans* from the colon and spleen, favoured a diagnosis of salmonella septicaemia. The salmonella infection probably took place shortly before death.

In the four patients with gastro-enteritis (cases one, two, three and four) the mechanism of death was similar; the violent diarrhoea and vomiting produced a precipitous decline in extracellular fluid with abnormal loss of sodium and chloride; eventually, as a result of a compensatory mechanism (Gamble, 1950) there was also a loss of potassium. In one of the cases an examination of post-mortem blood showed a serum sodium of 285 mgm. per 100 ml. and a potassium of 8·5 mgm. per 100 ml.

Extracellular dehydration may take place very rapidly (Marriott, 1950), as is illustrated in the first case, or more slowly as in the second, third and fourth cases. In the fourth case the patient developed dehydration in spite of fluid replacement. Following dehydration the terminal condition was extra-renal uraemia as evidenced by increased blood urea nitrogen concentration in most of the cases.

Source of infection

At the outset of investigations into the genesis of this outbreak suspicion fell on the staff of the bakery as a likely source of infection but repeated bacteriological examinations of specimens from those who were concerned in the manufacture of the pies did not yield any evidence that the infection had arisen from a carrier. Certain members of the staff who were examined during the second week of the outbreak were found to be infected with the organism, but with one exception they had all eaten meat pies of the suspected batches. The exception was a woman who had a history of spasmodic diarrhoea of emotional origin for a number of years. *Salm. bovis morbificans* was isolated from part of one specimen of faeces, the other part of the specimen being reported as negative by another laboratory. All subsequent specimens from this woman (sixteen or more) were negative and consequently there was some doubt as to the true value of this finding. Moreover, she worked in the pie section of the bakery on only one of the relevant days so that it is very unlikely that she could have been responsible for the outbreak.

Manufacture of the pies

Meat, some of it minced, from various butchers in the area was received in the bakery stores and placed in the refrigerator in large metal baths and covered with sacking.

On the evening of the day prior to use for pie manufacture, the meat was removed from the refrigerator and allowed to stand at store room temperature overnight. The following morning, the meat was minced if not already minced and mixed with other ingredients. The mixture was fed into hoppers which deposited a fixed amount of it into each pie case as it passed the hopper. The lid was then placed on each pie by hand and pressed down mechanically. After glazing with an egg wash the pies were baked, the period of baking and the oven temperature being recorded automatically.

After baking, the pies were cooled in open trays at bake-house temperature for up to four hours; a warm saline gelatine solution was then poured through the perforated lid. The pies were allowed to stand overnight whilst the gelatine set and were distributed by van the next morning.

Consideration of pie constituents

Of the various constituents of the pies only the meat and gelatine will be considered at any length. The majority of the other ingredients were used in the baking of other products from which no ill effects resulted.

Meat. This will not be considered in detail but there are two points of note. (i) On one of the days in question there was a shortage of meat for pie making and, to overcome this, part of a consignment of veal obtained from an emergency slaughtered calf was used. There is no suggestion that this was infected but one of the bakery staff described it as being "off and smelling hammy." This may account for some of the pies having a peculiar smell and taste. This must be emphasised because the others, even although

heavily infected with salmonellae did not have any marked peculiarity of smell, taste, or appearance, whereas the odour and taste of those containing the veal was immediately noticed by the consumers, some of them being guests at the tennis club party. (ii) Supplies received by the bakery from one butcher contained meat from the carcases of several animals sent for casualty slaughter. This meat was supplied to several butchers and in most cases was sold in large cuts and used fairly quickly so that any minor infection was presumably killed by domestic cooking. However, one carcase was supplied to a butcher eight days before the minced meat was received from him by the bakery. This is in marked contrast to the early oooking of the meat which went to domestic consumers.

Meat—Bakery procedure. As mentioned before, the meat, when received, was placed in metal baths in the refrigerator. These are not used in turn, but as a rule are completely cleared by the end of each week. As a result of this system the meat may be several days old when used, even if fresh when received.

From the 8th to the 15th June the bakery refrigerator was not working at freezing point but maintained a temperature of 40°—45°F.

During the period 9th-11th June the shade temperature in an exposed position varied between 46°F. (early morning) and 60°F. (early evening) so that the temperature in the store-room where the meat was left overnight would be well above 60°F. It was probably nearer 80°F. owing to the close proximity of the bake-house and the effects of the sun through various glass surfaces, so that a minor infection of the exposed meat could have become a major one overnight.

Gelatine. Several samples of the gelatine were submitted for bacteriological examination but in each case the result was negative. The same batch was used for the manufacture of cakes, from the consumption of which no ill effects were reported. The staff who "poured" the gelatine on the three critical days were similarly employed on the two preceding days when there is no evidence that the pies were contaminated.

A very extensive examination was made of these members of the bakery staff and, with one exception, there was no clinical or bacteriological evidence of infection. The exception was a woman who had eaten a meat pie on the 10th June. She was regarded as a victim of the outbreak and excluded from work immediately so that she could not have been responsible for the epidemic. Apparently there was an established practice in the bakery whereby any pies with broken casings or similar defects were made available to members of the staff. One man, an office worker, consumed such a pie when still warm from the oven and before the addition of gelatine. He suffered an acute attack of gastro-enteritis. No faecal examination was carried out until a week after the attack when the result was stated to be negative. However, some five months later his serum still showed a small rise in H(r) agglutinins, very probably the result of a previous *Salm. bovis morbificans* infection. This case is presumptive evidence against the possibility of infected gelatine.

The other constituents of the pies were used in other foods and those investigated, such as flour, fat, egg wash, etc., proved to be free from salmonellae.

An examination of all the working surfaces, cutlery, utensils and refrigerators in the bakery gave negative results and the premises were free from vermin. Faeces from the two bakery cats were also negative.

As a result of these investigations we were left with the inference that the meat was the probable source of infection and some attempt was made to establish whether this was so.

Investigation

Owing to the slow dissemination of information over the week-end and various other considerations this particular trail was well-nigh cold by the time it could be followed. It proved possible to identify the herd from which was derived the carcase which provided the eight day old mince. Examination of faeces from the remaining cattle in the herd which included a cow which after slaughter was found to have extensive lesions of septic peritonitis gave negative results. The Ministry of Agriculture Veterinary Investigation Officer from Liverpool undertook serological tests on two animals at a later date and one gave a positive reaction to *Salm. bovis morbificans O* at a titre of 1 : 80. This finding was considered to be of some significance but would have been of far greater value had it been possible to isolate a salmonella from the faeces of the animal.

TABLE 6

Serum agglutinins to Salm. bovis morbificans in 10 cows

No.	H (r)	O
1	<1 : 25	1 : 50
2	<1 : 25	1 : 25 Trace 1 : 50
3	<1 : 25	<1 : 25
4	<1 : 25	1 : 25
5	1 : 50	1 : 25 Trace 1 : 50
6	<1 : 25	1 : 25 Trace 1 : 50
7	<1 : 25	<1 : 25
8	<1 : 25	1 : 25
9	<1 : 25	1 : 25 Trace 1 : 50
10	<1 : 25	<1 : 25

We tried to assess the significance of this finding by examining sera from 10 cows, taken at random, in the Preston and Lancaster area (Table 6). The results may be summarised as follows: In three sera the agglutination tests against *Salm. bovis morbificans* were negative and in seven the reaction was positive to either H(r) or O at a titre of 1 : 25 or 1 : 50 which was not considered to be of significance, except in number one. In order to check the value of the serological findings, faecal specimens from the cows would have to be examined but circumstances made this impossible.

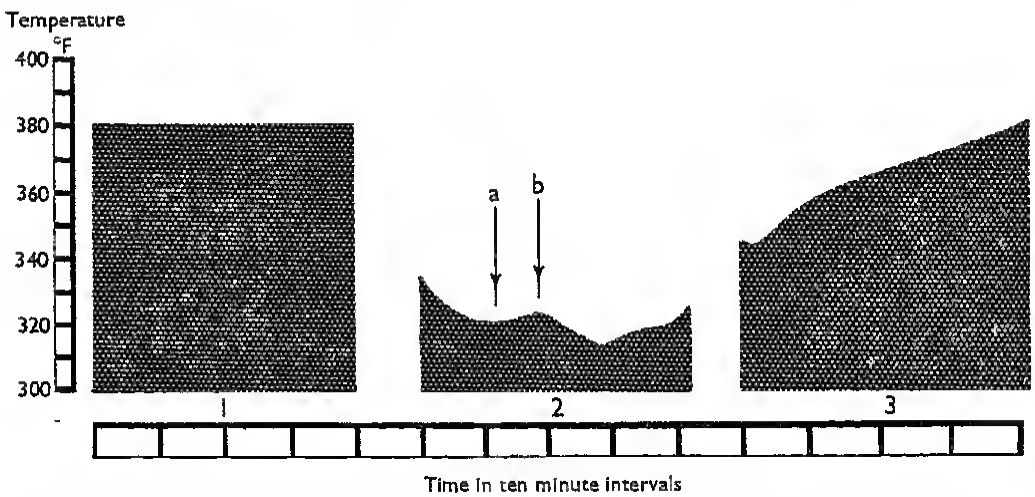
Assuming that the infecting organism was present in the meat before reaching the bakery the next question was whether or not the baking procedure was capable of destroying *Salm. bovis morbificans* when included in meat pies.

Controlled experiments using infected meat pies were carried out in bakery and laboratory ovens in an attempt to throw light on the matter. This extensive experimental work lasted several months and is described in detail in the second part of this report. A very brief summary of an experimental reproduction of the routine procedure in the bakery where the pies were infected may be appropriate at this juncture.

(1) The meat of 2 oz. and 4 oz. pies was inoculated with *Salm. bovis morbificans* and the pies were then baked in a commercial oven at 380°F. (4 oz. for forty minutes, 2 oz. for thirty-two minutes). The pies were examined bacteriologically at intervals of up to fifty-two hours; the organism was not recovered.

(2) The meat and dough of 4 oz. pies were inoculated with *Salm. bovis morbificans* and the pies were set aside in a warm room (96°-102°F.) for twelve hours, and were then baked at 380°F. for forty minutes. After removal from the oven and cooling, the pies were allowed to stand for two hours at room temperature, when a warm gelatine solution was added. The pies were examined at intervals of up to seventy-two hours but the organism was not recovered.

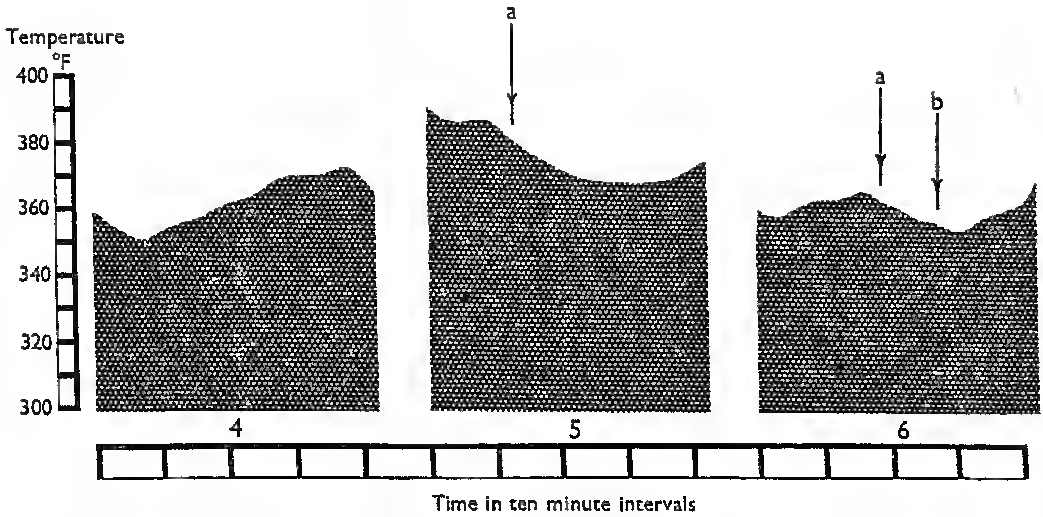
FIG. 3. Diagrams to show the conditions of time and temperature during the baking of meat pies and other products on the important days. (Nos. 1 and 7 are controlled experimental bakings.)



3,1. *Controlled experimental baking.* (Nominal conditions 380° F. for 40 minutes.)
One tray of 4 oz. pies was placed in the oven and the temperature remained constant at 380° F. throughout. (Total baking time 40 minutes.)

3,2. *Routine baking.* (Nominal conditions 380° F. for 40 minutes.)
Sixteen trays of 4 oz. pies and 16 trays of 1 oz. Queen cakes were placed in the oven when the temperature was already low (325° F.) and there was a further loss of heat. About 12 minutes later (*a*) the queen cakes were removed. Just as the temperature was beginning to rise 16 trays of 2 oz. fruit tarts were loaded into the oven and a further fall in temperature was recorded. By the time the pies and the fruit tarts were removed, the oven heat had only risen to 325° F. (Total baking time 42 minutes.)

3,3. *Routine baking.* (Nominal conditions 380° F. for 40 minutes.)
Sixteen trays of 4 oz. meat pies were placed in the oven at a temperature of 345° F. This caused an initial drop in heat, but as the doors were not opened again until the end of the baking period the temperature rose fairly steadily, eventually reaching 380° F. (Total baking time 42 minutes.)

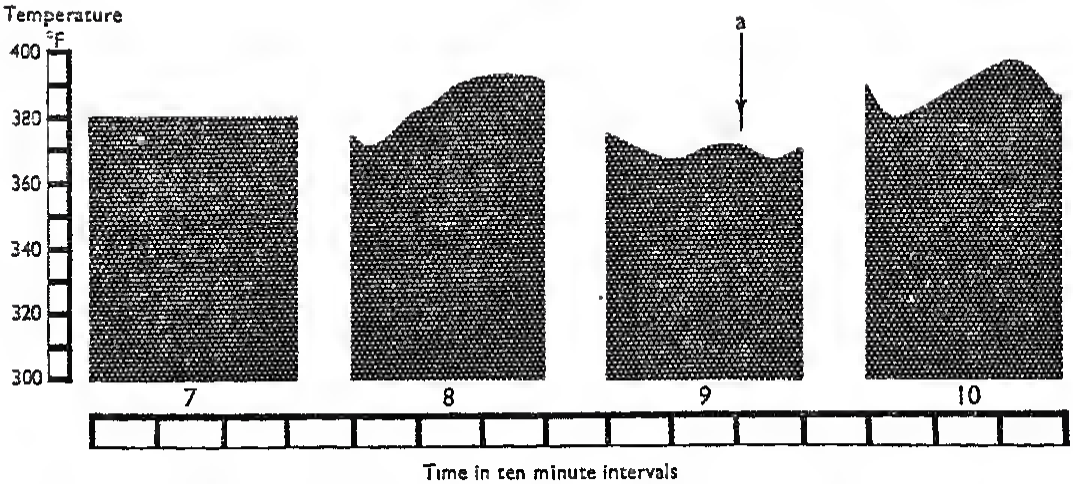


3,4. *Routine baking.* (Nominal conditions 380° F. for 40 minutes.)
Twenty one trays of 4 oz. pies were placed in the oven at a temperature of 360° F. As a result of this the heat fell for the first ten minutes, but, as the oven doors remained closed the temperature rose to a maximum of 372° F. about five minutes before the end of the baking period. The oven doors were then opened and there was a drop in temperature. (Total baking time 43 minutes.)

3,5. *Routine baking.* (Nominal conditions 380° F. for 40 minutes.)
Sixteen trays of 4 oz. pies were placed in the oven at a temperature of 390° F. The heat then dropped slightly and, just as it was steadying the oven doors were opened for the loading of 16 trays of 16 oz. sandwich cakes (*a*). This caused a marked drop in temperature which was only just being corrected when the pies and cakes were removed. (Total baking time 43 minutes.)

3,6. *Routine baking.* (Nominal conditions 380° F. for 40 minutes.)
Eight trays of 4 oz. pies and 16 trays of 2 oz. almond tarts were placed in the oven at 360° F. The temperature dropped and then began to rise, reaching a maximum of 366° F. The doors were opened twice during the next ten minutes first(*a*) for removal of the almond tarts and then again(*b*) for the loading of thirteen trays of old pastry. As a result of all these operations the oven heat dropped to 358° F. and had only just reached 375° F. when the pies were removed. (Total baking time 43 minutes.)

A clue to the source of the infection in this outbreak will be found in a careful comparison with the experimental bakings of the bakery conditions during the three days on which the infected pies were made. The oven temperature diagrams (Fig. 3) show the baking periods for ten batches of pies. Diagrams 1 and 7 show the conditions in the *experimental baking* where the pies were the only goods in the oven and the doors were kept closed during the whole period. At the initial loading of the oven there was only one tray to be put in, so that the effect on the temperature was negligible and the thermometer readings remained constant throughout the baking period. The experimental bakings provide a striking contrast to the state of affairs depicted in the remaining eight diagrams. These show the variations in oven temperature during the *routine baking* of pies, the conditions being very different. When the pies are loaded into the oven there are several trays so that the doors are open for a longer period. This, together with the large mass of pastry and the cold metal trays, produces a marked drop in oven temperature. Further, during the actual period for which the pies are being baked the oven may be opened several times so that goods with a shorter cooking time can be placed in the oven or removed.



3,7. *Controlled experimental baking.* (Nominal conditions 380° F. for 32 minutes.)
One tray of 2 oz. meat pies was placed in the oven at 380° F. The temperature remained constant throughout the period. (Total baking time 32 minutes.)

3,8. *Routine baking.* (Nominal conditions 380° F. for 30 minutes.)
Twelve trays of 2 oz. pies were placed in the oven at 375° F. After an initial drop the temperature increased steadily to 392° F. where it remained for the last ten minutes of the baking period. (Total baking time 30 minutes.)

3,9. *Routine baking.* (Nominal conditions 380° F. for 30 minutes.)
Eleven trays of 2 oz. pies and 16 trays of 16 oz. flans were loaded into the oven at 375° F. After the initial fall the temperatures rose to a maximum of 370° F. but dropped again(*a*) when the flans were removed. There was a final rise to 374° F., at which point the pies were removed. (Total baking time 30 minutes.)

3,10. *Routine baking.* (Nominal conditions 380° F. for 32 minutes.)
Four trays of 2 oz. pies and 16 trays of 16 oz. sandwich cakes were placed in the oven at 390° F. After the usual initial fall the temperature rose to a maximum of 396° F. and only fell again in the last few minutes when the doors were opened to remove the pies and cakes. (Total baking time 30 minutes).

The notes explain in detail what happened during each period. The effect on the temperatures is obvious from a glance at the diagrams.

Assuming that the infecting organism was present in the meat before it was filled into the pies and baked, there is very good reason to believe that it could have survived in many of the batches of pies which were made on the days in question. The addition of warm gelatine after baking and the fairly high atmospheric temperatures prevailing at the time would encourage the rapid multiplication of surviving organisms and thus produce the highly infected product which caused the outbreak.

Discussion

Virulence of the organism. From a careful survey of all the available evidence in this outbreak it would appear reasonable to conclude that the organism responsible for the many severe and at times fatal infections was highly pathogenic and extremely virulent. Although the writers themselves have had no experience of previous infections due to this salmonella type, cases reported elsewhere indicate that the organism is usually associated with relatively mild infections both in infants and adults (Seligmann *et al.*, 1946, Angrist and Mollov 1946, Atkinson *et al.*, 1944, 1947). A notable exception, however, was the organism concerned in the severe epidemic

in infants and young children reported by Mackerras and Mackerras (1949a) where the severity of the illness was greatest in infants of less than one year of age. In the present outbreak persons of all ages were affected, the greatest severity being seen in adults of whom five died. Consideration of the gravity of the symptoms in this epidemic and of the small amount of contaminated food consumed by certain of the victims, strongly supports the view that the causal organism was unusually pathogenic.

It is difficult to explain why a particular salmonella species should suddenly develop exaggerated virulence for all age groups only during the epidemic period. Some authors have suggested that strains of salmonellae may enjoy enhanced virulence in hot weather. Savage (1932) quotes experimental work by Singer who found that if meat infected with *Salm. enteritidis* was fed to dogs those animals maintained at summer temperature became ill whereas those living at winter temperature were not affected.

In view of the fact that the meat pies were the vehicle of infection in this outbreak, it may be assumed that the baking procedure resulted in some form of selection, organisms which survived the baking temperature certainly being more heat resistant and possibly more virulent. In addition there may be some growth factors in meat which affect the characters of the organism but there is no evidence as to what they may be or how they act.

The outbreak lasted for about seven days and may be considered to have ended on the 18th June. After it had subsided, it was noted that the incidence of secondary cases was very low and the illnesses relatively mild, suggesting that the epidemic strain had lost much of its former infectivity and virulence. At this time there existed in the affected area a large reservoir of infection in the many human faecal excreters of the organism and there was ample opportunity for the spread of infection by contact in work-places as well as in the home. During the investigation of a later outbreak of salmonella infection in another bakery in this area two of the staff who gave no history of previous illness were found to be excreting *Salm. bovis morbificans*. It would therefore appear reasonable to suggest that the low incidence and mild character of the infections in the post epidemic period indicate waning infectivity and decreased virulence of the strain, the reason for which we do not understand.

But, in a few of the patients infected early in the outbreak the organism would appear to have had the ability to retain some of its enhanced virulence, manifesting this in occasional or frequent clinical relapses with abdominal pain, diarrhoea and positive faecal cultures. Acute exacerbations of salmonella enteritis continued for periods of many months and in one of them for over a year. Again, the absence of secondary cases in these homes would suggest that the strains had become less infective thus simulating the conditions in the homes of the many symptomless faecal excreters. However, in the former it should be mentioned that the emphasis on good personal hygiene may have been partly responsible for limiting the spread of infection.

Toxin type of case. Regarding twenty patients who suffered severe attacks of gastro-enteritis after eating pies and from whose faeces the organism was never recovered, even after repeated examinations, it was suggested that toxins produced by the epidemic strain growing in the meat may have

been responsible for the symptoms. Where infection is by live salmonellae it is usually possible to demonstrate the organism in the excreta for several days during and immediately after the infection. The toxin hypothesis assumes that the organisms in the meat were killed during the baking of certain batches and that the ill effects were entirely due to the products of bacterial metabolism when growing in meat, or possibly to the dead organisms themselves. At the time of the outbreak it was not possible to obtain samples of the pies which caused the illness in these patients and consequently experimental work could not be undertaken.

A survey of the literature dealing with outbreaks in which there are strong grounds for suspecting toxic substances rather than living organisms as the cause of symptoms, whilst of interest, is not conclusive. The results of this mass of work, which has been performed over the last sixty years, can be divided into three groups:—

(1) Animal experiments in which evidence of toxin production was not demonstrated (Dack *et al.* 1928).

(2) Animal experiments in which some of the subjective symptoms of food poisoning other than gastro-enteritis were produced (M.R.C. 1947 f).

(3) Animal experiments in which typical attacks of food poisoning were produced, sometimes with fatal results (Geiger *et al.* 1928 and Braham *et al.* 1928).

These experimental findings suggest that the following points have an important bearing on the matter, (*a*) the age of the culture and the salmonella species used: (*b*) the resistance of the individual subject: (*c*) the physical conditions under which the subject, animal or human, is living: (*d*) the culture medium employed and the conditions of growth: (*e*) the manner in which the various products are administered, and, finally (*f*) whether bacteria-free filtrate or a heat-killed suspension of organisms in the culture medium was used.

In view of the fact that the pies concerned with the Lancashire episode were examined for the presence of salmonellae only, the possibility of other toxin-producing organisms such as *Staphylococcus aureus* being present in the pies cannot be excluded. We must therefore conclude that the organism responsible for rendering some of the meat pies toxic was not identified.

Chloramphenicol. As all the strains of *Salm. bovis morbificans* which were examined showed *in vitro* sensitivity to chloramphenicol in the concentrations employed in the disc method, this antibiotic was widely used in the treatment of patients during the acute infections, in clinical relapses and to a lesser extent in the carrier state. The results obtained were essentially similar to those reported in other salmonella infections treated with chloramphenicol (Seligmann *et al.* 1949, Woodward *et al.*, 1950, Pierret 1951, Weiner *et al.* 1951, Wildman, Nicol & Tee, 1951). In the acute stage of the illness the response was usually satisfactory; there was clinical improvement as evidenced by a fall in temperature and the subsidence of symptoms; two young children who were extremely ill responded well to this antibiotic and made good recoveries; the results are comparable with those reported by Marie *et al.* (1950) and Pierret *et al.* (1951). There is no doubt that this valuable antibiotic prevented many fatalities.

However, chloramphenicol failed to prevent clinical and cultural relapses and to eradicate the carrier state. The treatment of persistent carriers was disappointing and, in fact, valueless. As reported hy other workers (Weiner *et al.* 1951, Ross *et al.* 1950), the drug appeared to have a hacteriostatic hut not a curative effect.

The results were essentially similar to those ohtained by one of the authors (A.A.M.) in a small neo-natal outhreak due to *Salm. chester* (unpuhlished work, 1951), in which twenty infants were affected, all of whom showed rapid clinical improvement in the acute infections: there was no death hut the antibiotic failed to prevent relapses or to produce cultural clearance: some of the infants continued to excrete the organism for as long as 9-10 months after the illness.

Risk of Infection. The outhreak emphasises the possibility of infection being suddenly introduced into a very reputable bakery from an outside and unsuspected source with disastrous consequences to trade as well as to the health of the community. In this establishment the standard of hygiene was very high; there were no rodents in the building and no carrier of pathogens among the staff employed in the pie department.

Prevention of similar occurrences. It is clear to our minds that the meat was the cause of this serious outhreak and that the oven, under the system of mixed baking used at that time, was incapable of destroying the load of infection. This outbreak emphasises the need for the examination of all animals hefore slaughter and the inspection of all carcases hefore they leave the slaughterhouse. If this precaution is neglected outbreaks of food poisoning are inevitahle. However, the chances of infected meat pies resulting from such contamination can he reduced to the minimum in at least two ways. They are (1) hy careful inspection of meat in hoth public and private slaughterhouses and (2) by adequate cooking of the meat during processing.

Summary

This report deals with a large outbreak of *Salm. bovis morbificans* food poisoning which occurred in West Lancashire in June and July, 1953, where over 1,149 persons were affected of whom five died. The clinical and lahoratory findings in a group of forty patients and the clinical and necropsy findings in the five fatal cases showed that the epidemic was due to infection by *Salm. bovis morbificans*, the vehicle of infection being meat pies manufactured in a single bakery.

There was no evidence to suggest that the pies had heen contaminated by a carrier in the bakehouse staff and after consideration of all the relevant information it was concluded that the ultimate source of infection was the meat.

Comparison of controlled experiments with the hakery temperature records showed that contamination in the meat could have survived the baking process.

There was no evidence that gelatine introduced the contamination.

Acknowledgments

We would like to express our thanks to Dr. Joan Taylor for identifying the epidemic organism and for her opinion on the agglutination tests and their significance; to Drs. Anthony Rickards and G. W. Storey for clinical and

necropsy records of four fatal infections (Cases 2, 3, 4 and 5); to Dr. O. K. Guyer for access to the records of patients in the Deepdale Isolation Hospital; to Dr. S. C. Gawne for the figures which have been used in fig. 2; to Dr. A. Dodd and his staff for most helpful co-operation throughout the whole of the investigation; to Drs. J. S. G. Burnett, J. Walker, and G. G. Wray, Medical Officers of Health, and the sanitary staffs of their departments for their help in the collection of specimens and obtaining information; to Mr. John B. Wright and the staff of the Bacteriology Department of the Group Laboratory for technical assistance; and finally to Mrs. G. H. Philip for her willing, competent and patient secretarial assistance in preparing the typescripts.

APPENDIX A

Statistics furnished by the Salmonella Reference Laboratory shewing the total number of salmonella strains received and the number of isolations of S. bovis morbificans during the period 1923-1953.

Year	Total Number of Salmonella strains Received	*Salm. bovis morbificans* (included in totals)
1923–1939	428	8
1940	139	3
1941	120	—
1942	104	3
1943	262	6
1944	453	3
1945	506	6
1946	748	2
1947	689	9
1948	908	14
1949	1,304	13
1950	1,234	23
1951	1,612	11
1952	1,083	7
1953	1,409	74

APPENDIX B

Rapid screening method for the emergency examination of faecal specimens

THE method adopted during the outbreak for the rapid examination of faecal and other specimens was as follows:—

For primary faecal cultures (and also for other specimens) desoxycholate citrate agar (D/C agar) and selenite F. broth were used. Originally both selenite F and tetrathionate—brilliant green broth had been used, but as the former gave better results it was now decided to use it alone throughout tbe investigation. Suspected salmonella colonies on the D/C agar plates were subcultured to peptone water and urea medium and after overnight incubation the organisms which produced urease were discarded, the remainder being further investigated in the following way. The peptone water cultures were centrifuged and the supernatant fluid transferred as completely as possible to small test tubes so that examination for indole production could be made. All the indole-positive cultures were discarded. If the organism had not produced indole the deposit from the peptone water was suspended in saline and

used for slide agglutination tests commencing with Polyvalent Salmonella Phase 1 and 2 sera for primary screening and then Polyvalent Salmonella Phase 2 serum. The strains in Phase 2 were subcultured for phase reversal in the usual manner and then, together with those already in the specific phase, tested against (H(r) O (6, 8,) sera.

Certain strains of salmonella from food handlers and other special cases were examined by a longer method, including fermentation tests, slide agglutinations with bacterial suspensions and occasional confirmation by tube agglutinations; many of them were also checked by the Salmonella Reference Laboratory, Colindale. It was noted that when the strains identified by the shorter procedure were checked in full by the longer method there was never any discrepancy in the results obtained. One very interesting feature which characterised the whole investigation was that when the first serological examinations of the organism were carried out most of them were found to be in the specific phase (phase 1).

PART II

Contamination of Meat Pies with particular reference to the effect of baking on Salmonellae and the risk of post-baking infection by careless handling

by A. A. Miller and F. Ramsden

Introduction

During the investigation reported in the first part of this Report one of the investigators (C. G. N.) suggested certain simple laboratory experiments to determine the effect of baking on artificially contaminated meat pies and possibly to throw light on the source of the infection in the outbreak. The initial experiments were made in the bakery oven where the infected pies had been baked, the remainder being conducted in the sterilising oven of a hospital bacteriological laboratory. The results of these experiments together with a critical assessment of the recorded thermometer readings of the bakery oven for the days on which the pies were infected, produced strong evidence that the meat was contaminated before it was baked in the pies and that salmonellae could have survived the baking temperatures.

In the wake of this incident yet another but less extensive outbreak of salmonella food poisoning occurred in a neighbouring town. Again the vehicle of infection was meat pies. The investigation of the second outbreak presented features which suggested further experimental work, the emphasis on this occasion being on contaminated liquid gelatine which was added to the pies after they had been baked.

The results of both sets of experiments together with technical methods and illustrations are set out in the following pages.

Previous experimental work with meat pies

In the literature there is very little reference to experimental contamination of meat pies with salmonellae and their destruction or survival after being subjected to baking temperatures for varying periods.

In 1902 an outbreak of salmonella food poisoning in Derby gave Delépine the opportunity of making observations on this subject. The outbreak was due to infected meat pies and the organism isolated from them was a member of the Gaertner group. There were over two hundred and twenty-one cases and four deaths. The investigation showed that the meat probably became infected after mincing when it was left standing uncovered on the floor of the chopping house and open to contamination from a tub containing pigs' intestines.

In his experimental work Delépine used a thermometer to record the temperatures attained in meat pies during baking. When the pies were baked he removed them from the oven and immediately plunged the bulb of the thermometer into the meat. He found that the temperature reached in a pie which appeared to be well baked (but which was really underbaked)

did not exceed 47·2°C., and that in the centre of a pie which was grossly overbaked it did not rise beyond 86·6°C. Furthermore there was a difference of several degrees between the temperatures of various pies. Delépine pointed out that a batch of pies prepared in a hurry might be so cooked that bacteria could survive in the meat during baking.

He added that meat was a poor conductor of heat and that the baking temperature might be insufficient to kill pathogenic organisms. More recently Dewberry (1950) states that observers in America, Germany and England who were investigating the temperatures reached in cooking such food enquired whether or not these were sufficient to destroy any pathogenic organisms which might be present, but there is no mention of the conclusions reached by these investigators.

The main features of salmonella food poisoning outbreaks due to meat pies

The reported outbreaks of food poisoning in England (1878–1911) and on the Continent of Europe (1888–1910) have been briefly described by Savage (1913). In seventy-eight of the British outbreaks in which food was the vehicle of infection, some sixty-six were associated with meat, and in the majority the meat was prepared or processed. In no less than 38 per cent of the cases brawn or meat pies was the food consumed.

Fourteen of the outbreaks were associated with meat pies (including pork, veal and beef) and in some of them other foods such as brawn were also eaten.

These outbreaks were reported from Retford (1887), Carlisle (1889), Portsmouth (1890), London (1895), Hatton (1898), Chadderton and Oldham (1898), Derby (1902), Bedford (1906), St. Annes-on-Sea (1908), Mossley (1908), Whitefield (1908), Blackpool (1908), Wrexham (1910), and Chesterfield (1911).

In most of these outbreaks the bacteriological investigations were incomplete but it is interesting to note that *Bact. paratyphosus B.* was isolated in one and that *Bact. suipestifer* and Gaertner group bacilli were each isolated in four more.

An examination of the Continental reports shows that a much higher proportion of outbreaks were due to eating flesh itself, not infrequently raw or as some form of chopped meat, whilst in a number of instances some variety of sausage was the vehicle of infection.

In more recent times Savage and White (1925) described the following outbreaks:—

Derby 1921. Salm. derby

In October, 1921, an outbreak of salmonella food poisoning at Derby was associated with pork pies. There were thirty-seven cases in some of which the symptoms were severe, lasting as long as three weeks. There was no death. A salmonella, later identified as *Salm. derby*, was isolated from one of the pork pies of the incriminated batch and also from the tank water which was used for washing the large gut of pigs at the slaughter-house. No excreta of the patients were examined. The pork pie and bacon factory and the slaughter-house for the pigs were combined premises. The meat pies had been baked at a temperature of 400°F. but the baking time

was not stated. After baking and cooling the pies were filled with gelatine in the customary way. It was suggested that the infection may have lain in the water tank and that gelatine solution contaminated with water from the tank conveyed the organisms to the pies.

City of London 1922. *Salm. typhi murium*

In September, 1922, in the City of London, there was a small domestic outbreak of food poisoning in which three persons were affected. The history is that on the 2nd September several pieces of meat including ox cheek, cow's heel and skirt of beef were stewed for two hours, left in a saucepan until the next day and again stewed for three hours. The meat was eaten for dinner on the 3rd of September. The unconsumed portion of it was then made into a pie which was baked and stored until next day. Three people ate the pie and became ill. One other person who ate it was unaffected but a dog had an attack of diarrhoea after eating scraps of it. *Salm. aertrycke* was isolated from the excreta of all three persons affected. None of the suspected food was available for examination. The meat would appear to be the most likely source of infection but there is no indication as to the way in which it became infected.

Various outbreaks—1919–1931 salmonellae

Savage (1932) analysed one hundred and twenty-one food-poisoning outbreaks due to salmonellae in the period 1919–1931 and found that in sixteen the vehicle of infection had been meat pies: pork pie in ten, veal and ham in three and "various" in the remainder.

Staffordshire 1930. Salmonella suipestifer

The same author (1932) described a small outbreak due to a meat pie infected with *Salm. suipestifer* which occurred in Staffordshire in 1930 in which there were eight cases with three deaths. The pork pie which was the vehicle of infection was eaten four days after it had been baked.

Prestatyn 1949. Salm. typhi murium

In a small outbreak at Prestatyn in 1949 sixteen persons who ate meat pies from a cooked meat shop suffered from gastro-enteritis. Several of the illnesses were severe and most of them lasted for seven to ten days. *Salm. typhi murium* was isolated from the patients, from one of two portions of meat pie examined, and from several mice caught on premises where the pies were prepared. An examination of the food-handlers gave negative results.

The meat for the pies was cooked on the day of purchase and was then allowed to cool overnight in an uncovered dish in the store. The following day the meat was minced and made into pies which were sold about twenty-four hours later.

Of the fifty pies sold it seemed likely that 8–10 were contaminated. How the infection came about is not clear but there seems little doubt that mice were the source. They may have had access to the meat in the store, or again, may have soiled the mincing machine, which was not sterilised.

Standards of hygiene in the bakery were fairly good and the owners were not aware that mice were present. It was assumed that they had come from an adjacent building (Ministry of Health, 1950).

Manchester—Torridon, 1950. Salmonella aberdeen

Brockbank *et al.* (1950) reported an outbreak of food poisoning due to *Salm. aberdeen* in which the vehicle of infection was meat pies manufactured in Manchester. There were fifty cases in all, twenty-nine in the Manchester area and 21 in a party of boy scouts who ate the pies on their way to Scotland and became ill in the Torridon area.

The symptoms were pyrexia of short duration, usually, but not always, accompanied by diarrhoea and vomiting. Several of the patients were severely ill and one underwent appendicectomy in the acute state of the illness. The investigation did not reveal the source of the infection.

Northampton, Bucks. and Midlands, 1951. Salm. minnesota

In December, 1951, an explosive outbreak of food poisoning due to *Salm. minnesota*—a salmonella unusual in England—occurred in South Northamptonshire and North Bucks. in which the vehicle of infection was pork pies manufactured by one firm. Cases were reported also in the Midlands and they too were found to have eaten pies from the same batch. There were five hundred cases in all. The investigation showed that the infecting organism had been introduced in the warm gelatine which was added to the pies after they had been baked and allowed to cool. (Ministry of Health, 1953 a.)

Aberdeen area, 1951. Salm. minnesota

In October and November, 1951, a small outbreak due to *Salm. minnesota* occurred in the Aberdeen area, where again the vehicle of infection was considered to be meat pies. The investigation is not reported. (Ministry of Health, 1953 b.)

Lytham and West Lancashire, 1953. Salm. bovis morbificans

This outbreak is the subject of this report.

Wakefield, 1953. *Salm. typhi murium*

In July, 1953, in the City of Wakefield, there was an outbreak due to *Salm. typhi murium* in which the vehicle of infection was manufactured meat products, principally pork pies. The total number of persons affected was two hundred and six. The causal salmonella was isolated from the faeces of one hundred and ninety of these. The incubation period was 12-18 hours. The presenting symptoms included abdominal pain, vomiting and diarrhoea. In the main the illness was of moderate severity though some patients were severely affected and a few were but mildly indisposed. The duration of illness was approximately three days. There were two deaths.

Salm. typhi murium was cultured from a portion of unconsumed pork pie and also from the person who had eaten part of it, as well as from a portion of boiled ham. Investigation showed that the bakery worker who filled the pies with meat and placed them in the oven for baking had herself suffered from gastro-enteritis, but had remained at work. Her salmonella infection had followed the consumption of food purchased outside the City of Wakefield. Some of her fellow workers including one who added warm gelatine (" gravy ") to the pies after they had been baked and cooled were infected by eating food contaminated by her. It is interesting to note that *Salm. typhi murium* was found in the gelatine (" gravy ") but not in the meat

of the pies, indicating that in this outbreak the warm gelatine ("gravy") provided an excellent culture medium for the infection introduced by the symptomless excreter handling it.

Preston, 18th and 19th September, 1953. Salm. typhi murium

In September, 1953, in Preston, Lancashire, there was a food poisoning outbreak due to *Salm. typhi murium* in which the vehicle of infection was meat pies produced by a large bakery. The total number of persons giving positive faecal cultures after eating the infected meat pies was one hundred and six; three more were negative. Some of those affected in the outlying county districts were not investigated. Clinically they suffered mild or moderate attacks of gastro-enteritis. There was no death. *Salm. typhi murium* was isolated from six members of the bakery staff and from four of the firm's van drivers, none of whom, according to their own statements, had eaten any of the pies from the suspected batch. The bakery has a rule whereby employees never eat any of the firm's products. At the time of the outbreak (19th September), two of these ten workers, one baker and one van driver had gastro-enteritis. It was learnt that the baker who prepared the gelatine solution which was poured into the cooling pies, after baking, was himself a symptomless excreter of *Salm. typhi murium*. It was further noted that the warm gelatine had lain in an open container some three feet from the hand-basin used frequently by the drivers to wash their hands before loading the vans. Clearly there was opportunity for contamination of the gelatine solution by splashing from the basin or from shaking the hands before drying. The same strain of *Salm. typhi murium* ('phage Type 4) was isolated from the bakery workers and van drivers, and from the meat pies which had caused the outbreak.

Normal procedure used for the manufacture of meat pies

Flour and fat are weighed into a bowl, placed on a machine, and made into a crumbly mix. Water, in which salt has been dissolved, is added and the mixing continued until a paste has been formed.

Whilst this operation is in progress, meat (in pieces or bought ready minced) is mixed with potato and put through a mincer. The resultant mince is placed in a bowl, salt and pepper are added, together with sufficient water to make the mix of suitable consistency for automatic depositing.

The paste is divided and placed into tins for mechanical moulding and filling. After having been filled with the mince-potato mixture the pie is "egg-washed" round the top edge. A perforated lid is placed on the case by hand and the two are sealed together by mechanical pressure. The pie is now ready for baking.

After baking the pies are removed from the tins and placed on wire trays to cool.

During the time of preparing and baking the pies, other members of the staff are preparing the gelatine.

Salt and gelatine are weighed out into a container and mixed to a smooth paste with cold water. Boiling water is then added to the required amount. After cooling to approximately the same temperature as the pies, the gelatine

is poured through the perforated lids and the whole allowed to cool and set, usually overnight.

In most bakeries there is a set time and temperature for the baking of pies but the time is often varied by the baker in a purely empirical manner to compensate for variation in oven temperature, moisture content and the like, his object being to produce a pie of pleasing appearance.

The gelatine is often mixed and allowed to cool in open containers and in some places is allowed to stand on the floor in uncovered containers for several hours with the consequent risks of contamination.

In many bakeries the pouring of gelatine into the pies is done by ladling with a jug from the bulk container and then pouring from the jug into the pies. In such circumstances the solution when poured is often fairly cool, sometimes very little above melting point.

It can thus be seen that there are several opportunities for pies to be infected after baking and that the "rule of thumb" methods of baking could allow a pre-existing infection of one of the pie constituents to survive the baking period.

Experiments using Salmonella bovis morbificans

D (1) *A preliminary experiment*

A young culture of *Salm. bovis morbificans* was inoculated into the meat of each of twelve 4 oz. and twelve 2 oz. freshly prepared meat pies which were then left at room temperature for an hour. At the end of this time those pies, together with six non-inoculated controls, were baked at 380°F. (±1°F.) in the oven of a commercial bakery. The 4 oz. pies were heated for forty minutes and the 2 oz. pies for thirty-two minutes.

After removal from the oven and cooling for four hours at bakehouse temperature (80°F.) all the pies were removed to the laboratory, where they were kept at room temperature (70–74°F.) and sampled at periods ranging from about four to fifty-two hours after baking. The organism was not recovered from any of the pies.

D (2) *A more comprehensive experiment*

The meat of twenty-one 4 oz. pies and the dough of nine others were inoculated with *Salm. bovis morbificans* mixed cultures of various ages and left at room temperature (96–102°F.) for twelve hours. The pies were then baked at 380°F. (±1°F.) for forty minutes in a baker's oven. After cooling for three hours at bakehouse temperature (80°F.) gelatine solution was added and one hour later the pies were removed to the laboratory.

Heat indicator tubes (see appendix 3) had been embedded in the meat of six of the pies and after baking it was found that they had changed colour from dark red to bright green.

The test pies, and six non-inoculated controls which had been heated in a similar manner were kept at room temperature (68–74°F.) and individual pies were examined at intervals ranging from five to seventy-two hours after baking.

The organism was not recovered from any of the pies.

As a result of these two experiments the following conclusions were drawn:—

(*a*) The baking temperature of 380°F. for forty minutes for 4 oz. pies or 32 minutes for 2 oz. pies appeared to be effective in killing all viable salmonellae in the experimentally infected meat pies, as the organism could not subsequently be demonstrated in spite of the favourable growth promoting conditions during the pre- and post-baking periods.

(*b*) The baking temperature and time were effective whether the infection was in the dough or in the meat.

D (3) *A further small experiment*

The meat and dough of three 2 oz. meat pies were inoculated with a mixed culture of *Salm. bovis morbificans* of various ages and heat indicator tubes were buried in the meat. After remaining at room temperature (66–88°F.) for sixteen hours the pies, together with a non-inoculated control, were baked in the laboratory oven at 320°F. for the following periods:—

One test pie for thirty minutes.
Two test pies for sixty minutes.

After the pies had cooled for one hour gelatine was added to them and they were then left in a warm room (68–92°F.) for forty-eight hours. Examination at the end of this time showed that after baking for sixty minutes at 320°F. salmonellae were not recovered, whereas after baking at this temperature for thirty minutes many of the organisms survived.

After thirty minutes baking the heat indicator tube had not changed colour, whereas after sixty minutes it was bright green.

Experiments using Salmonella typhi murium

E (1) The meat of fourteen 2 oz. pies and the dough of fourteen others were inoculated with mixed cultures of *Salm. typhi murium* of various ages; heat indicator tubes were buried in the meat. Together with eight non-inoculated controls these pies were kept at room temperature (78–84°F.) for seventeen hours and then removed to a bakery.

All pies were baked at 480°F. for twelve and half minutes and at 420°F. for a further thirteen minutes—a total of twenty-five and half minutes.

After cooling and the addition of gelatine the pies were kept at room temperature (60–70°F.) for six hours and examined serially at intervals during the next sixty-six hours.

Salmonellae were recovered from two of the pies in which the meat was inoculated and from two of the group in which the dough was inoculated. Thus the organism survived in four of the pies (approximately 14 per cent) after baking at 480°F. and 420°F. for a total time of twenty-five and a half minutes. All heat indicator tubes were bright green when removed from the pies.

E (2) The meat of six 2 oz. pies was inoculated with mixed cultures of various ages of *Salm. typhi murium* after which the pies were kept at room temperature (78–84°F.) for twenty-four hours, when they were then baked at 320°F. for periods varying from thirty to sixty minutes. After cooling and

the addition of gelatine, the pies were kept in a warm room (60–70°F.) for forty-eight hours prior to examination.

On examination the organism was not recovered from any of the pies so that presumably a temperature of 320°F. for thirty minutes or longer was sufficient to destroy the viable salmonellae in this experiment.

Combined experiments using Salm. bovis morbificans and Salm. typhi murium

Two final experiments were made to show the effect of baking on the destruction of *Salmonellae typhi murium* and *bovis morbificans;* mixed cultures of various ages of both organisms being separately inoculated into the meat only: both groups of contaminated meat pies being baked in the same oven at the same time.

F (1) The meat of sixteen 4 oz. pies was inoculated, eight with *Salm. typhi murium* and eight with *Salm. bovis morbificans.* After incubation at 78–80°F. for twenty-two hours the pies were baked in the laboratory oven at 320°F. for periods ranging between ten and sixty minutes.

After cooling and the addition of gelatine the pies were kept at room temperature (64–76°F.) for forty-eight hours.

Subsequent examination showed that *Salm. typhi murium* was recovered after baking for thirty minutes or less at 320°F. but was not recovered from pies which had been baked for thirty-five minutes or longer. *Salm. bovis morbificans* was recovered after fifty minutes baking at 320°F., but was not recoverable after sixty minutes baking at this temperature. Equal quantities of inoculum were used in all cases and the results of this experiment indicate that *Salm. bovis morbificans* is endowed with a greater resistance to heating than is *Salm. typhi murium.*

F (2) The meat of eleven 2 oz. pies was inoculated, six with *Salm. typhi murium* and five with *Salm. bovis morbificans.* After incubation at 76–80°F. for twenty hours, the pies were baked in the laboratory oven at 320°F. for periods ranging between ten and sixty minutes.

After cooling and the addition of gelatine the pies were kept at room temperature (64–76°F.) for forty-eight hours.

Subsequent examination showed that *Salm. typhi murium* was not recovered after baking for fifty minutes or longer at 320°F. (viable organisms were recovered after forty minutes) whereas *Salm. bovis morbificans* was not recovered after sixty minutes baking at this temperature. (Viable organisms were recovered after fifty minutes.)

These experiments again showed that in the meat medium *Salm. bovis morbificans* was more heat resistant than *Salm. typhi murium.* This finding agreed with the thermal death point determination in fluid medium. (See appendix 1, section 4.)

The fact that *Salm. typhi murium* survived at thirty minutes in 4 oz. pies but at forty minutes in 2 oz. pies is probably explained by the age of the cultures. In Experiment 1 the age range was from one to fourteen days, but in Experiment 2 from one to forty-five days. It has generally been found in our work that older cultures seem to be more heat resistant.

Appearances of pies after baking

The following is a description of the appearance of meat pies when baked for various periods of time at a temperature of 160°C. (320°F.).

Time of baking in minutes	*Appearance*
0 (unbaked)	The pie looks doughy. The pastry is very moist. The meat is reddish in colour; wet and soggy in consistency.
10	The pie still looks obviously underbaked and doughy, but the surface of the pastry is dry. The meat is still wet and reddish in colour.
20	The pie looks obviously underbaked and doughy. The pastry is now fairly dry. The meat is still reddish in colour and rather damp. Gravy from the pie has boiled up on to the lid.
25	The pie looks obviously underbaked. The pastry is dry and "scaling." The meat is fairly firm but there is no change in colour. The gravy on the lid of the pie has dried up.
30	The appearances are similar to those at twenty-five minutes but there is further general loss of moisture.
35	The pie has a similar appearance to that at thirty minutes except that the meat has now taken on a greyish colour. The pastry is faintly brown in parts.
40	Similar appearance to the pie baked for thirty-five minutes; the "browning" of the pastry has gone further. The pie still looks slightly underbaked.
50	The pie appears to be adequately baked. The meat is firm and greyish in colour; the pastry is brown.
60	The pie appears to be well baked. The meat is solid and well cooked. The pastry is well browned.

It will be seen from a comparison of the appearances listed above and the combined experiments described on p. 37 that *it is possible to have a pie which appears to be adequately baked yet from which it is possible to recover viable salmonellae.* This explains and emphasises the inherent risk of "rule of thumb" baking methods which rely entirely upon the appearance of the baked product.

Consideration of the effect of different baking temperatures on the meat pie constituents and upon infecting organisms

(1) From the foregoing experiments in the laboratory oven it would appear that an ideal time for baking, from the purely bacteriological point of view, would be 320°F. for 60 minutes. The organism was never recovered from meat pies after this treatment. However, in the bakers' view this temperature

is far too low—some would describe such treatment of pies as "boiling" rather than baking. The result of this long exposure to a comparatively low temperature results in a product which is too dry for commercial acceptance.

Bakeries tend to use a procedure involving a much higher temperature for a shorter period. This sudden blast of heat has the effect of "sealing" the pastry and meat mass, thus preventing drying of the main bulk, as happens at low temperature. The result is a commercially acceptable pie but one in which pre-existing salmonellae can survive. (See Experiment 1 with *Salm. typhi murium* on p. 36.)

Between these two extremes, i.e. (i) 320°F. for sixty minutes and, (ii) 480°F. for twelve and half minutes and a further thirteen minutes at 420°F. there is the baking procedure which employs a temperature of 380°F. or thereabouts for some forty minutes.

This latter method gives a pie which is acceptable to the public and in which salmonellae should not survive, if the temperature is maintained for the stipulated time.

In view of the fact that the pastry needs baking at a high temperature for a short time, and meat to ensure sterility needs a long exposure to heat, another possible system would be to cook the meat before adding it to the pie. If this pre-cooking were adequate to sterilise the meat, the baking could proceed rapidly at high temperature, the optimum condition for the pastry.

(2) *Effect of low and high temperature baking on heat penetration.* When meat pies are baked at high temperatures the outer surface of the meat mass coagulates rapidly. This coagulum is a poorer conductor of heat than the unaltered wet meat and it is possible that it forms an insulation for the core of the mass and prevents, or seriously retards, heat penetration after the first few minutes in the oven.

In low temperature baking the water in the meat mass is heated slowly until it almost reaches boiling point (see appendix 3) and the heating tends to be more uniform. The water is not "sealed in" as is evident from the experiments in the laboratory oven where the "gravy" boiled on to the upper surface of the pie lid.

(3) The similarity in survival times of salmonellae shows that there is little difference in heat penetration in 2 oz. and 4 oz. pies. There is a simple physical explanation for this. In the products used in our experiments the difference in size was mainly one of area, the thickness being substantially the same for 2 oz. and 4 oz. pies. As a result of this the heat had the same distance to penetrate, the shortest course it could travel being from the upper and lower surfaces.

Experiments dealing with the contamination of pies in the post-baking period

J. (1) In the outbreak of *Salm. typhi murium* infection in Preston, 1953, summarised on page 34, contamination of the gelatine solution was thought to be caused by splashing from a wash-hand basin or by shaking the wet hands before drying them. To test the validity of this hypothesis

the following experiment was carried out. A porcelain evaporating dish containing warm gelatine solution was placed on the floor of a room about four feet from a wash-hand basin for about two hours; four petri dishes containing D/C agar were placed around the gelatine dish. At intervals of about sixty minutes three people "washed" infected hands carelessly, with splashing, the procedure being as follows:—Wearing rubber gloves, the operator dipped his hands into a suspension of *Salm. typhi murium* and then washed in warm water without using soap. On turning away from the wash-bowl towards the lay-out, he then dashed the residual drops of water from his hands, towards the uncovered gelatine and the exposed plates (Fig. 4). During the test period the gelatine was also exposed to air-borne contamination. After two hours the gelatine was used to fill freshly baked meat pies which were allowed to incubate at room temperature before examination.

J. (2) A second experiment was made to show the spread of contamination by careless handling of liquid gelatine. A thumb which had been infected with *Salm. typhi murium* and then washed as before, came into contact with hot gelatine solution whilst picking up a container. The basin of contaminated gelatine was incubated at 37°C. for one hour and from it measured quantities were poured into freshly baked meat pies.

All the pies in experiment (1) and (2) were found to be infected with the contaminating salmonella, both in the gelatine and the meat, when examined after 24, 48 and 72 hours; the four plates of D/C agar used along with the gelatine in experiment (1) showed numerous colonies of *Salm. typhi murium*:—

Plate	*Number of colonies*
A.	63
B.	286
C.	576
D.	340

J. (3) A third experiment was made to show the spread of contamination by the careless handling of meat pies which had been baked, jellified and allowed to cool. The index finger of a previously infected and washed hand was smeared over the top of six of these pies in a serial manner. The meat and gelatine from all the six pies were found to contain the contaminating organism.

Consideration of gelatine penetration of the meat mass—extension by growth into meat of infection introduced by gelatine solution

In the first of the immediately preceding experiments it was found on opening the pies that the gelatine filled the space between the meat and pastry but had only penetrated the meat mass to a distance of some 2–3 mm. This was presumably due to the addition of cool gelatine to cold pies. On cooling, the meat filling sets in a fairly compact mass and the gelatine is cooled fairly rapidly by the meat and sets before it can soak into the mass for more than

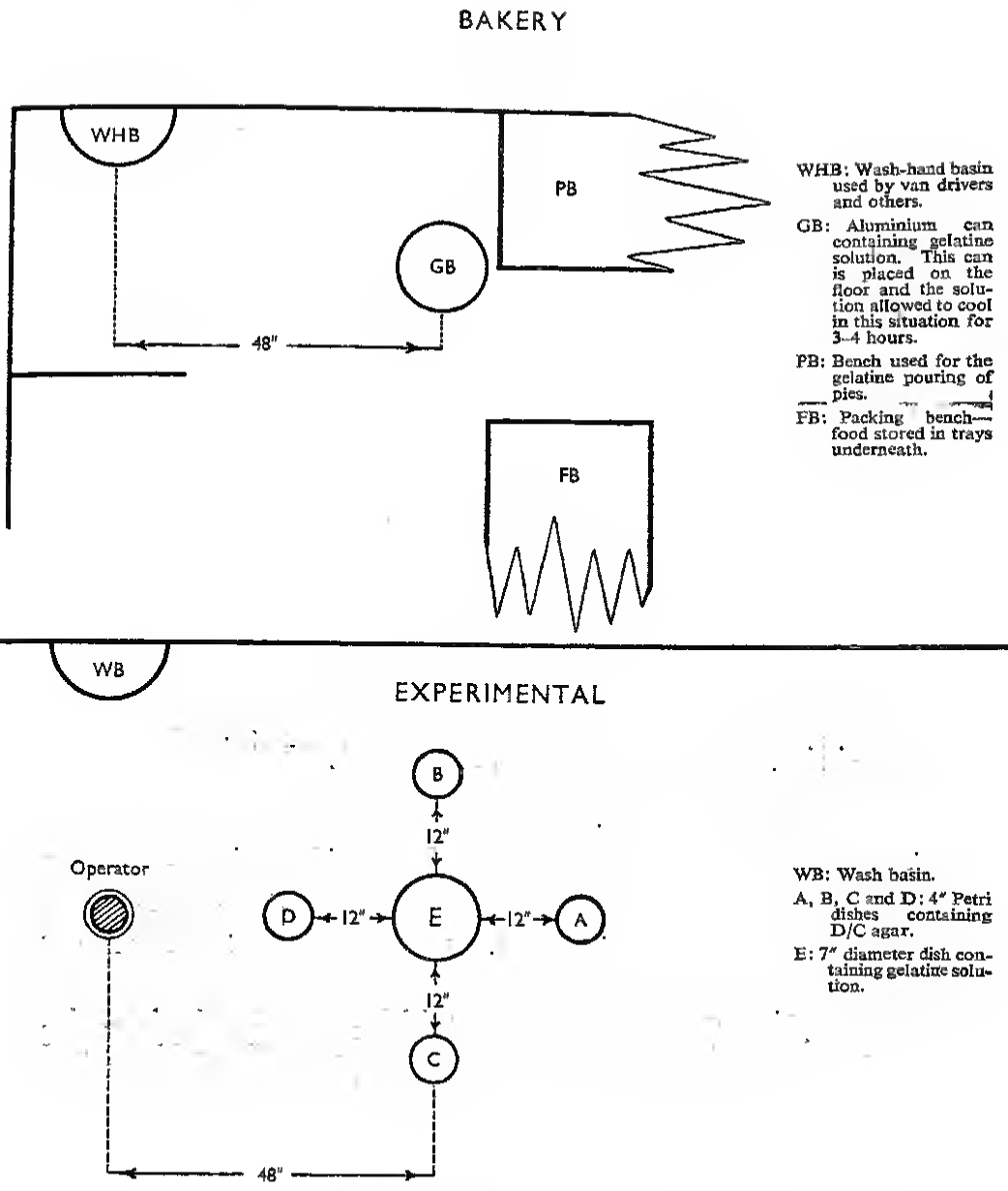


FIG. 4. Comparison of Bakery and Experimental Conditions. In the bakery the wash basin is in a corner near a window. The gelatine container was placed on the floor at the end of the pouring bench, this position being some four feet from the wash basin. The experimental layout reproduced the spatial relationship.

a few millimetres. The presence of a fair proportion of fat in the meat may also be a partial barrier to penetration (Fig. 5).

When the pies were taken apart for bacteriological examination, the above points having been noted, we decided to take samples of meat from the centre of the pies where gelatine could not be seen. In this sampling, precautions were taken to prevent organisms from being mechanically transferred to the middle from the gelatine and outer parts of the meat mass.

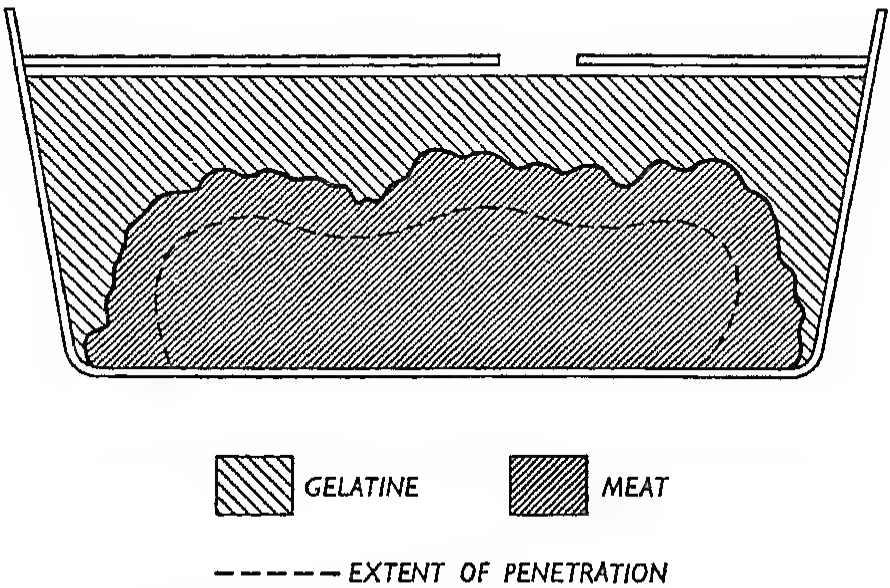


FIG. 5. Diagrammatic cross-section of a completed meat pie showing the extent to which the gelatine penetrates the meat mass.

These samples from the centre of the pie still yielded viable salmonellae so that in the post-baking period the organisms had grown from the surface throughout the meat mass. The reverse process, extension of infection from meat to gelatine occurs quite commonly when the meat is the source of infection.

It will thus be apparent that, if there is a fairly long post-baking incubation period, an infection in any part of the pie will, in all probability, result in a generalised contamination of the whole product.

APPENDIX 1

Technical Notes

(1) *Suspensions*

All strains of *Salm. typhi murium* and *Salm. bovis morbificans* used in the experiments were isolated from excreta of patients or from contaminated meat pies examined in the course of investigating the outbreaks of food poisoning in West Lancashire and in Preston.

Several cultures of the same and of varying ages which had been grown on nutrient agar were washed off with physiological saline and centrifuged. The deposits were mixed, resuspended in saline and diluted to the strengths stated.

Experiment	*Age Range*	*Strength—organisms per ml.*	*Inoculum*
D.1	18 hours	$2{,}275 \times 10^6$	0·5 ml.
D.2	4–30 days	$1{,}972 \times 10^6$	0·5 ml.
D.3	1–14 days	$1{,}000 \times 10^6$	0·5 ml.
E.1	1–70 days	$2{,}500 \times 10^6$	0·5 ml.
E.2	1–42 days	$2{,}500 \times 10^6$	0·5 ml.
F.1	1–14 days	$2{,}500 \times 10^6$	0·5 ml.
F.2	1–45 days	$2{,}500 \times 10^6$	0·5 ml.
J.1	1–14 days	250×10^6	—
J.2	1–14 days	250×10^6	—
J.3	1–14 days	250×10^6	—

(2) (a) *Inoculation of pies with Salmonellae suspensions*

The volume of suspension was measured with a hypodermic syringe and then thoroughly and intimately mixed with the dough or meat, whichever was being inoculated.

(b) *Examination of pies* (excepting experiments dealing with the contamination of pies in the post-baking period).

Meat. The whole of the meat mass was removed from the pie, freed from gelatine and pastry, and dropped into 200 ml. of selenite F. medium. After chopping with a knife, the suspension was thoroughly macerated using a heavy glass rod with a jumped end.

Gelatine. When samples of gelatine were to be examined the lid of the pie was first cut away and a sample of the gelatine, free from meat, taken from inside. This was dropped into 20 mls. of selenite F. medium and shaken up after the first hour's incubation.

Pastry. The sides of the pie case were cut away, freed from adherent meat and gelatine, dropped into selenite F. medium and thoroughly macerated therein.

Heat indicator tubes. These were dissected out from the meat mass and placed (without breaking) into 20 mls. of selenite F. medium.

The fluid enrichment medium was in all cases, incubated at 37°C. for forty-eight hours, being subcultured on to D/C agar at twenty-four and forty-eight hours. The agar plates were examined after 18–24 hours' incubation at 37°C.

(c) *Examination of pies—post-baking period contamination* (page 39)

The procedure was similar to that used in the other experiments, with one exception. Instead of taking the whole mass of meat, a sample was taken from the centre where the gelatine did not appear to have penetrated.

(d) *Experiments dealing with post-baking contamination* (page 39).

(i) The diagram comparing bakery and experimental conditions gives the dimensions of the dishes and the spatial relationships.

The suspension used for contaminating the gloved hands was contained in a porcelain evaporating dish. The fingers were dipped therein and then washed without soap in warm water (50°C.) and on turning to the layout, the residual drops were dashed from the hands—as is so commonly done after washing.

The temperature of the gelatine was not allowed to fall below 40°C. The very large bulk used in a bakery would keep its heat for several hours but the small volume used in the experiment needed warming occasionally.

(ii) In this experiment only the gloved thumb and index finger were dipped into the suspension of salmonellae. After washing the hands in warm water (50°C.) without

soap a dish of liquid gelatine (temperature 40°C.) was picked up by the infected hand, the thumb being in contact with the fluid. This was an attempt to reproduce the conditions which arise when gelatine is ladled out from a bulk container with a jug.

(iii) After contaminating and washing the hands as in the first experiment the gloved index finger only, of one hand, was smeared over the gelatine of six prepared pies, one after the other. It was done to simulate the condition where a person with infected hands touches a series of pies.

(3) *Culture media used in experimental work*

Desoxycholate citrate agar. (D/C agar).

The formula used for D/C agar was Hynes' modification of Leifson's medium (Mackie and McCartney, 1953) to which 1 gramme per cent. of sucrose had been added.

Selenite F. medium.

This was prepared according to the formula of Leifson as quoted by Mackie and McCartney (1953).

Gelatine

A 17 per cent. w/v solution of pure powdered gelatine in 0·85 per cent. aqueous sodium chloride was used in all the laboratory work. The concentrations of gelatine and salt used by the different commercial bakeries varied somewhat and some firms added meat juices, hence the use of the term "gravy" for the gelatine solution. No attempt was made to follow the commercial formulae exactly.

(4) *Thermal death point of the organisms*

The thermal death point of both the organisms used in the experiments was determined with the following results:—

Salm. bovis morbificans was killed after 20–22 minutes at 80°C. (176°F.).

Salm. typhi murium was killed after 14–16 minutes at 80°C. (176°F.).

The determinations were carried out in 1/4 strength Ringer's solution (500×10^6 organisms per ml.) and it was found that cultures with age variation of from one to eighteen days gave results within the limits stated.

APPENDIX 2

Suggestions for improvement of meat pie manufacture

(1) Once a temperature for meat pie baking has been decided upon it should be rigidly maintained. The difficulties in the maintenance of a set heat under bakery conditions are several, one is that after placing pies in the oven other goods may be put in and removed before the pies are finished.

Another factor which has a great bearing on the question of an even temperature is oven design. In our experimental work we have had some experience of three types and gained some knowledge of a fourth. They are as follows:—

(a) *Laboratory oven.* This is an electrically heated thermostatically controlled oven with two doors at the front. Under the conditions used for baking pies (i.e. very rapid removal of pies one at a time and manipulation of the regulator) the baking temperature was kept within 1 or 2°F. of the nominal temperature. If, however, this type of oven was used in general baking where large trays are used the doors would be open for longer periods and the temperature drop would then be considerable. This type of oven is not found in commercial establishments.

(b) *Rotating oven.* Simply described, this is a device rather like the big wheel seen on fairgrounds enclosed in a heated box (see fig. 6 and plates I and II, which show two models). The wheel rotates at moderate speed and thus presents each "paddle" in turn to the door of the oven. The paddles will each hold two baking trays so that if a dozen trays were to be inserted this door would be open for some time (the time needed for six "paddles" to pass) and this results in considerable heat loss. If a product is to be baked for forty minutes it has to travel round several times and in the meantime other trays are being inserted and removed so that fluctuation of temperature in mixed baking is the rule rather than the exception.

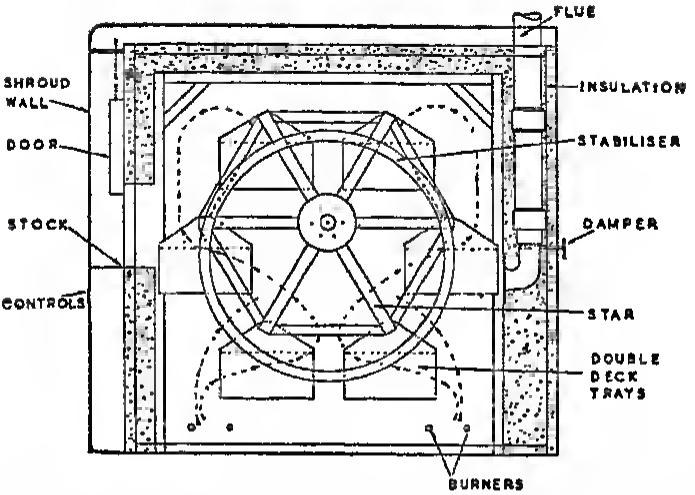


FIG. 6. Diagrammatic cross section of a reel oven showing the arrangement of the parts.

On the other hand, unless care is taken, baking for a long period with the door closed results in an increase of temperature above the stated level. (Fig. 3 shows variations which can be, and are produced, during routine " mixed " baking as it is carried out in commercial practice.)

(c) *Conveyor type of oven.* In this pattern the products are placed on a conveyor belt and pass through a heating chamber (see plate III). The heat loss from the end openings is fairly constant and the products endure the full heat for about three-quarters of their time in the chamber. Provided that the heating system and the period in the chamber are adequate this type of oven should give reliable time/temperature baking. The rate of travel of the conveyor is variable to allow for products which require different baking periods.

(d) "*Travelling*" *oven.* This is a modification of the oven described in (c). The conveyor is enclosed in the oven with the exception of one end, the point where the trays are loaded. Behind each tray position is a baffle which closes the opening as it passes, thus minimising heat loss. The ovens, usually gas fired, have several rows of heating jets and so quickly overcome the effects of the introduction of cold pastry, trays, etc. (see plate IV).

The upper chamber into which the product first enters is, as would be expected, hotter than the lower.

The speed of travel round the oven is variable and, when very long baking times are required a sliding door can be used to cover the open end. However, even when this end is left open the heat loss is constant and the temperature does not usually vary more than 5°F. in routine baking.

(2) Care in the handling of pies and their constituents is essential as these products are usually about twenty-four hours old when consumed so that any post-baking contamination, or infection which survived baking, would have adequate time for multiplication. The pie, being a conglomeration of meat, pastry and gelatine, is an ideal culture medium.

However, contamination in the bakery is not the only source of infection. Before reaching the bakery the pie constituents pass through several hands, any one of which may be contaminated, and the finished pies are frequently handled between leaving the bakery and being consumed.

Meat. The first handling of the meat is in the slaughterhouse when the animals are killed; some of these establishments and their methods of working leave much to be desired. It is unfortunately, easily possible for contamination to be spread from " casualty slaughter " to healthy carcases, e.g., through the common, but reprehensible practice of wiping down the carcases with a rag saturated with warm water. The custom of washing meat with a clean cloth and *fresh* hot water for each animal has much to commend it but often the same bucket of water and the same deplorable cloth are used for several animals. Samples of water and cloth used for this purpose have been examined in this laboratory and have shown gross contamination.

The inspection of meat which, because of apparently poor quality is graded as being suitable only for manufacturing purposes is particularly important. Usually this grading is given for deficiency in muscle or bad set but the occasional sample of pale looking, rather soggy meat may be so graded. It was from just such a specimen that this laboratory isolated *Salm. dublin* (another animal salmonella), while Soulsby *et al.* (1950) have reported the isolation of *Salm. typhi murium* from the carcase of a bullock which was submitted for meat inspection.

After leaving the killing floor the meat is manhandled several times before reaching the bakery. Often it is carried on the floors of vans which are soiled by the feet of the driver who, leaving his driving cab, walks around on the road and jumps into the van to sort out the meat. Thus all manner of filth from the roads can be transferred to the carcases.

Further, after such handling the meat may be minced and kept for several days before using. In addition, refrigeration equipment used for storage is sometimes inefficient. It is also common to find that meat which is to be used for baking is removed from the cold room and allowed to stand at room temperature for 14–18 hours before baking. There is thus ample opportunity for meat to be contaminated and time for multiplication of any organisms which are introduced.

(4) On occasions it has been suggested that the meat used in pies should be pre-cooked. (Brockbank *et al.*, 1950). The two main methods by which this could be performed are boiling and baking. If the meat is boiled it results in a rather wet mass. For the housewife this is acceptable because the meat is placed in the pastry case which is supported by a basin or baking tin. After baking, the bottom of the case is often soggy from the gravy but, as the pie is usually served directly from the dish this presents no difficulty. In commercial practice, however, the pie is removed from the tin soon after baking and the crust must be capable of being handled without additional support; if it were soggy the pie would fall apart and this happens sometimes with the present method of manufacture. To overcome this "wetness" the boiled meat would have to be drained and this would result in the loss of the normal physical appearance as well as reducing the nutritional value.

A further objection to the boiling of meat is the possibility of a surplus being carried over to another day with the resultant possibility of growth of a heat resistant strain of *Clostridium welchii* (Hobbs *et al.*, 1953). If the meat were boiled in large pieces some salmonellae might also survive as the heat might fail to penetrate to the centre of the lumps.

The alternative method, that is, baking, whilst overcoming the problem of wetting the pastry, would present difficulties in the process of mechanical deposition due to the dryness of the meat. The pie would also be very dry if the meat had been pre-baked and then subjected to further heating when the complete pie was baked. The resultant product would probably be unsaleable. Thus pre-cooking of the meat appears impracticable in large scale baking although it may be satisfactory in domestic practice.

After having been baked pies are kept at bakehouse temperature for some eighteen hours before delivery to shops where they are kept at room temperature until sale. The period in the bakery, the temperature of which is usually high, is an ideal one for the incubation of any organisms present. The treatment during delivery, whilst being excellent in the case of some establishments is poor in others; pies are carried in open trays and can be handled with the dirty hands which almost invariably result from driving a van.

The standards of hygiene in some of the smaller, and even a few of the larger shops are capable of improvement. Food is frequently handled, sometimes by customers as well as staff, and is also exposed to airborne contamination.

Gelatine. In the dried state, if it is well packed, gelatine is usually sterile, but danger of contamination arises as soon as it has been dissolved in water. The solution is often allowed to cool for several hours in open containers and is then poured into the pies by a primitive ladling process. Frequently the temperature is low at this stage, often very little above the melting point. Hence this excellent culture medium may be exposed to airborne and manual contamination when it is at an ideal temperature for promoting the growth of organisms.

Flour. Flour should be kept dry and free from rodent attack. The work of Scott Thomson (1953) has shown that salmonellae may survive in dry flour for forty-five weeks or longer and actual multiplication can take place when flour, or the sacking containing it, becomes damp.

Egg-wash. This is usually made from "liquid egg" which is packed in drums, or from frozen egg yolks which are tinned. In this laboratory salmonellae have not been isolated from the former product, although other laboratories have done so. However, some twenty-six batches of Canadian frozen egg yolks were examined by this department and the results were rather surprising. All yielded *Bact. coli* (faecal type 1) and salmonellae were isolated from six of the samples (about 23 per cent.). The types present were *Salm. bareilly* (1) *Salm. tennessee* (3) and *Salm. oranienberg* (2). (It should be noted however that the examination of the frozen egg yolks was not related to the meat pie investigation.)

(3) In view of the rather archaic and somewhat dangerous procedures used in the preparation and use of gelatine it is strange, or fortunate, that there has not been more trouble from contamination. The gelatine after being dissolved in boiling water should be boiled for five minutes, kept in a covered reservoir and not allowed to cool below a reasonably high temperature (say 170°F.).

The gelatine could be run from the reservoir by means of a short pipe (fig. 7) thus avoiding "dipping in" with a jug. Alternatively, the risk of contamination

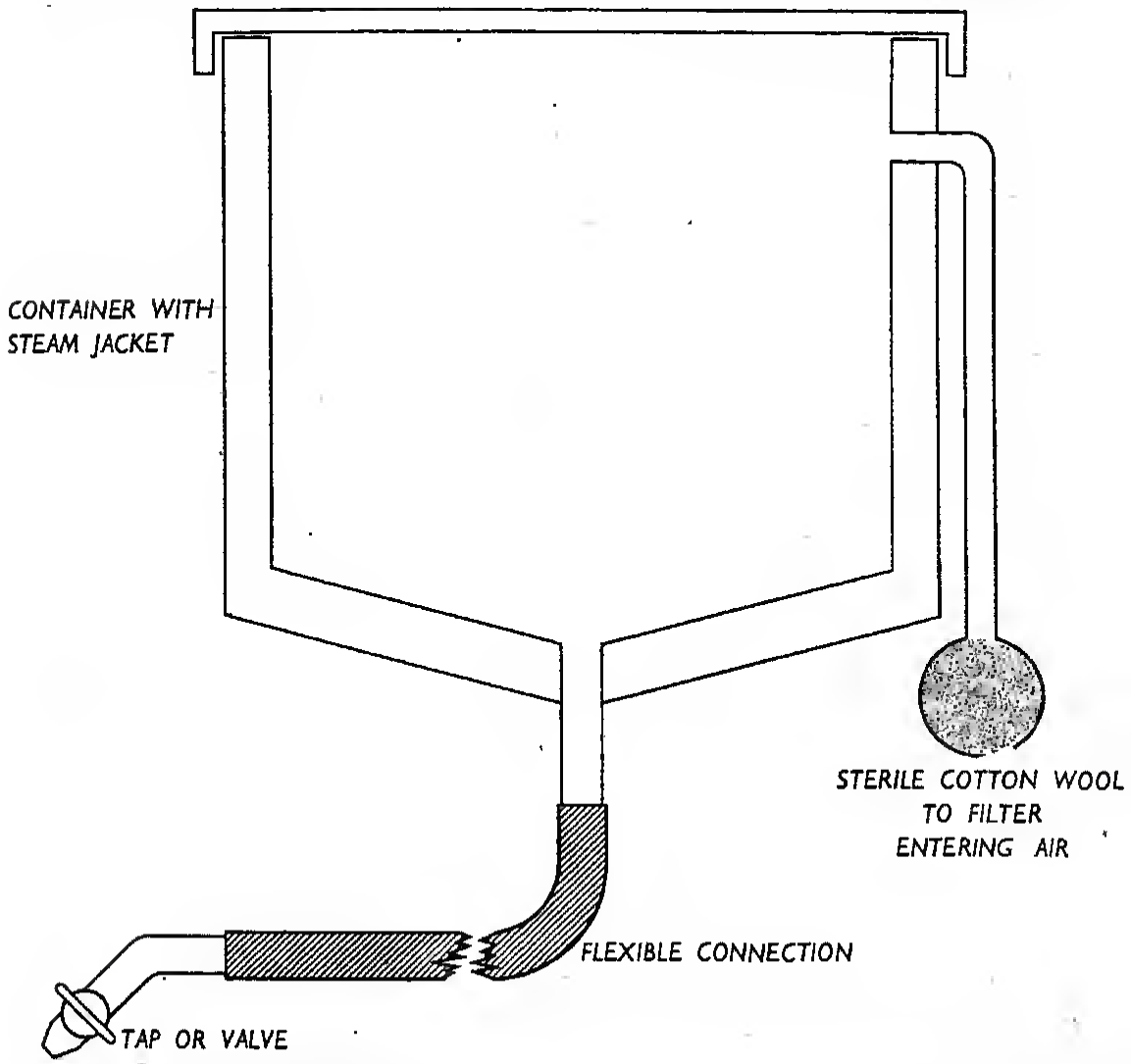


FIG. 7. Gelatine reservoir. This type of reservoir is suggested as a means of overcoming the objections to the present method of ladling from the bulk container with a jug.

could be reduced by lowering the *p*H of the gelatine solution to 4·5–5·0. This slight acidification of the solution would be relatively easy to achieve. When gelatine is dissolved in water and salt added the resultant solution is acid, being about *p*H 6 or even lower, depending upon the purity of the constituents. The addition of a small quantity of an organic acid (e.g. citric or tartaric) would bring about the further reduction in *p*H, would be non-toxic and virtually tasteless in the presence of the other pie constituents. The addition of meat juices to the gelatine solution, as practised by some bakeries, also results in a lowering of the *p*H value as these juices are acid in reaction.

The boiling and slight acidification of gelatine solutions tends to impair the setting properties but this can be overcome by slightly increasing the amount of sheet or powdered gelatine used.

APPENDIX 3

Temperatures reached in the centre of meat pies during baking

In oven experiments to determine this temperature, three methods were used:—

(1) Heat indicator tubes (a screening method).

(2) Thermometers.

(3) Thermocouple with potentiometer.

(1) Heat indicator tubes are commercially prepared for use in sterilization of dressings for surgical use. Each consists of a small sealed glass tube measuring 60 × 6 mm. containing a red-brown fluid which is a buffered dye solution. When the tubes are heated to 115°C. (239°F.) for twenty-five minutes the liquid changes to a bright green colour. This change also takes place if the tube is heated for an equivalent shorter time at a higher temperature.

The manufacturers give the following description of their product:—

"The liquid in the Sterilizer Control Tubes is an aqueous solution of a substance (chosen according to the range of time and temperature to be measured), which, when heated with water at a sufficiently high temperature will undergo hydrolysis to yield an acid. With this is a rather complex mixed indicator which is red in alkaline solutions and which turns green when the *p*H becomes low enough. The solution is completed by the addition of a buffer salt—commonly a phosphate—which ensures that the solution is alkaline at the start and only becomes acid after considerable hydrolysis of the main component has occurred.

When therefore, a tube containing one of these solutions is heated at an appropriate temperature, the hydrolysis of the main component causes a gradual decrease in *p*H to which the indicator responds by turning first brown, then amber coloured and then green. The nature and quantities of the components are all adjusted to the particular conditions to be fulfilled."

In the many oven experiments with heat indicator tubes it was noted that in the baked pies from which viable salmonellae were recovered, the colour change in the liquid had taken place (the same as in the baked pies which were sterile) indicating that in the centre of the pie a temperature had been reached which would normally destroy salmonellae. Consequently doubts were cast upon this method. One possible explanation was that only part of the glass tube was completely buried in the centre of the meat; one or both ends were often in contact with pastry and therefore would be exposed to a higher temperature than would be reached in the centre of the pie; the heat would be conducted along the glass producing the colour change in the liquid and thus giving a false temperature reading for the centre of the pie. This method was critically examined by further oven experiments.

(2) *Thermometer readings of the meat in the laboratory oven*

Twelve four ounce pies—performed in a gas heated laboratory oven—two thermometers through the top, one to record the oven temperature and one to record the

temperature reached in the centre of the meat pie—readings recorded at five minutes intervals for up to sixty minutes—meat contaminated with salmonella cultures of varying ages.

One meat pie at a time was placed on a small platform on the upper shelf of the oven, the top of the pie being about two inches from the top of the oven. Through a hole in the top of the oven a thermometer was introduced into the centre of the pie. That part of the thermometer which was exposed to oven heat was lagged with cork. The first graduation visible outside the oven was 65°C. consequently readings could not be taken until the temperature bad risen above this point. The second thermometer recorded the oven temperature (see fig. 8).

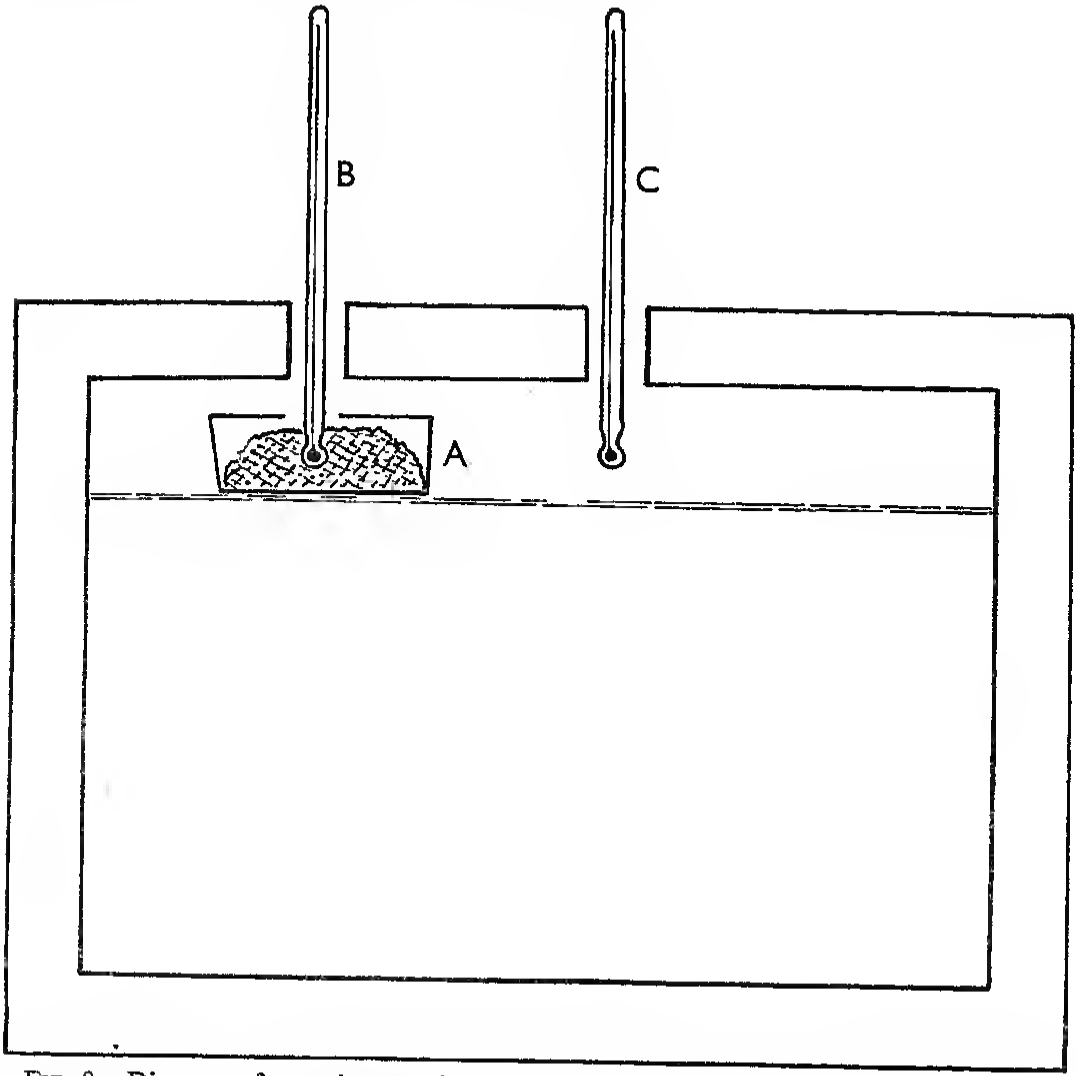


FIG. 8. Diagram of experiment using gas heated laboratory oven and thermometers to determine temperature reached during baking of meat pies.

A. Meat pie on top shelf of oven.
B. Thermometer with bulb immersed in meat.
C. Thermometer to determine oven temperature (the cork lagging is not shown).

The oven was well heated before commencing the experiments so that a brief temperature drop of about 10°C. occurred when opening the door to place the pie inside. Readings of the meat pie thermometer were made at five minute intervals after the temperature had risen to about 65°C, the time taken for this rise of temperature being about twenty minutes. Graph No. 1 in fig. 9 shows that in the centre of the pies temperatures of 80°C.–90°C. were reacbed after twenty-five minutes, 90°C.–95°C. after thirty minutes and 100°C. after forty minutes. When heating was continued up to ninety minutes there was no further rise in the temperature of the meat.

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The maximum temperature reached in the centre of the meat pie was 100·5°C. which is slightly above the boiling point of pure water. (Fig. 9.)

The heat indicator tubes compare very unfavourably with the thermometer readings and must therefore be regarded as an unsatisfactory method of estimating temperature in meat pies. They serve as a screening device suitable for control of sterilization of surgical dressings but are not precise enough for scientific work. Consideration of the thermal death points of *Salmonella typhi murium* and *Salmonella bovis morbificans* in fluid medium (see Appendix 1, Section 4) suggested that the temperatures reached in the centre of the meat pie during the baking period of sixty minutes, 320°F. (160°C.) under experimental conditions, would be sufficient to destroy any salmonellae which might be present. This assumption was supported by the bacteriological findings in the twelve pies used in these experiments. They had each been inoculated with cultures of *Salm. bovis morbificans* of varying ages and had been incubated at temperatures of 68°F.–73°F. before and after baking. The baking time was sixty minutes and the oven temperature 320°F.(160°C). Subsequent examination showed that none of the pies harboured surviving salmonellae.

(3) *Thermocouple with potentiometer*

(*a*) Five four ounce meat pies—baked in the electrically heated laboratory oven at a temperature of 320°F. (160°C.) for sixty minutes—a thermocouple introduced into the centre of the meat pie was attached to a potentiometer and recordings made at five minute intervals for the sixty minutes baking period.

As in the experiments with thermometers, one pie at a time was baked. The copper/constantan thermocouple was insulated to prevent any moisture from the pie causing a short circuit. The jointed exposed end was placed in position in the pie and the other end connected to the potentiometer, the copper wire being attached to the positive contact. The potentiometer readings were converted to temperatures (°C.) by the use of a standard table.

Graph 2 shows the mean of the readings obtained and it will be seen that they agree closely with those obtained when a mercury-in-glass thermometer was used. (Fig. 9.)

(*b*) Six four ounce meat pies—baked in the electrically heated laboratory oven at a temperature of 380°F. (193°C.) for forty minutes—thermocouples were introduced into the centre of the pie and into the air space between the meat and pastry. Potentiometer readings from each set of leads were taken at five minute intervals during the baking period.

The main experimental details are the same as those in 3 (*a*) above, the only differences being the use of a higher temperature and two thermocouples.

Graph 3 shows the mean of the readings obtained in the six experiments.

It will be seen that the temperature in the meat rose rather more rapidly and reached 100°C. approximately ten minutes earlier. The final temperature attained was however still only slightly above the boiling point of water. (Fig. 9.)

As would be expected, the temperature in the air space rose fairly rapidly but, in the baking time allowed did not go above 110°C.

The pies in both sets of experiments using thermocouples were contaminated with *Salm. bovis morbificans*. After baking at 320°F. for sixty minutes, or 380°F. for forty minutes, viable organisms were not recovered.

Conclusions

The practical value of these experiments lies in the findings that during the baking periods (320°F. for sixty minutes or 380°F. for forty minutes) the temperature in the centre of the four ounce meat pies rises to a height *sufficient to destroy all salmonellae.*

It is therefore essential that meat pie manufacturers should maintain careful control of baking times and temperatures in order to produce not only a saleable product but one which is wholesome and free from infection.

The main consideration which stresses the need for adequate baking is the risk that bakeries may be supplied with contaminated meat (see page 46). This risk is one which cannot be entirely excluded even with careful meat inspection. However, *adequate baking can and should effectively combat the chances of food poisoning arising from this source.*

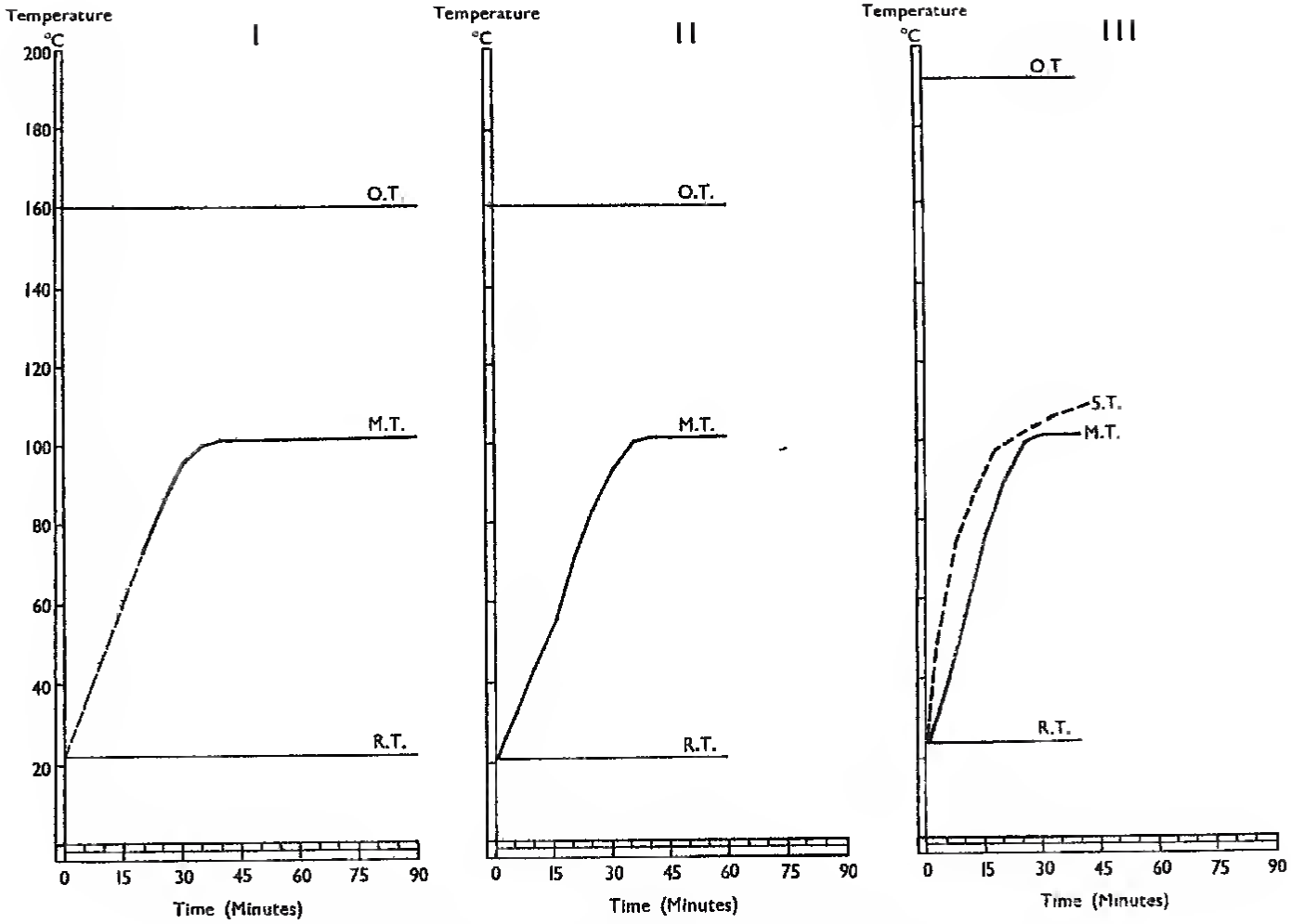

FIG. 9. Graphical representation of temperature in laboratory baking experiments.
Graph I using thermometer. Graphs II and III using thermocouples.
O.T. = oven temperature; R.T. = room temperature; M.T. = temperature in meat;
S.T. = temperature in air space between meat and pastry.

APPENDIX 4

Recommendations in respect of Baking Practice

From consideration of the experimental work and the above discussion we offer the following suggestions in respect of bakery practice as safeguards in the manufacture of meat pies.

A. Meat used in pies should be fresh, of good quality, stored under proper refrigeration and handled as little as possible. Clean meat, of course, implies that the working procedure in some slaughter-houses requires drastic improvement.

B. Where slaughtering and baking are combined the same staff should *not* work in both departments concurrently; a better arrangement would be to conduct the two businesses on separate premises.

C. Meat used in pies should be minced immediately before use, on, or near the bakery premises and any excess should be discarded.

D. An adequate temperature and time formula for the baking of pies should be worked out for each bakery and, once found, should be strictly followed. Our findings suggest that 380°F. for forty minutes for four-ounce pies and 380°F. for thirty-five minutes for two-ounce pies produce an acceptable product and one in which salmonellae do not survive. The observance of this formula implies careful regulation of baking practice especially with regard to the loading of rotating or conveyor ovens in such a way as to prevent the new cold load from vitiating the desired results.

E. After baking, pies should be covered and cooled fairly rapidly. After the addition of gelatine it is desirable to store pies in a room in which the temperature does not exceed 50°F.

F. Gelatine solution should be boiled for five minutes after being prepared and should be kept in a closed reservoir at a temperature of not less than 170°F. (Hobbs, 1950). Delivery to pies should be through a pipe rather than by ladling. The reservoir and all fittings should be thoroughly cleaned every day as a routine practice.

G. Pies should be packed in sealed, transparent covers (as soon as setting is complete) to prevent handling and air-borne contamination.

H. In accordance with the existing practice in many of the larger food premises, regular instruction in personal and bakery hygiene should be given by a responsible member of the staff.

In addition there should be supervision of the bakery staff with special regard to illnesses through which food may be dangerously contaminated. Intelligent supervision and advice about treatment cannot be over-emphasised.

I. Adequate washing facilities should be provided for, *and used by* the bakery staff, preferably with the use of sterile paper hand towels or hot-air hand driers.

J. Adequate suitable storage, free from vermin, should be available in all bakeries.

K. All equipment and working surfaces in bake-houses should be so designed that they are easy to keep clean; and *are in fact, kept clean.*

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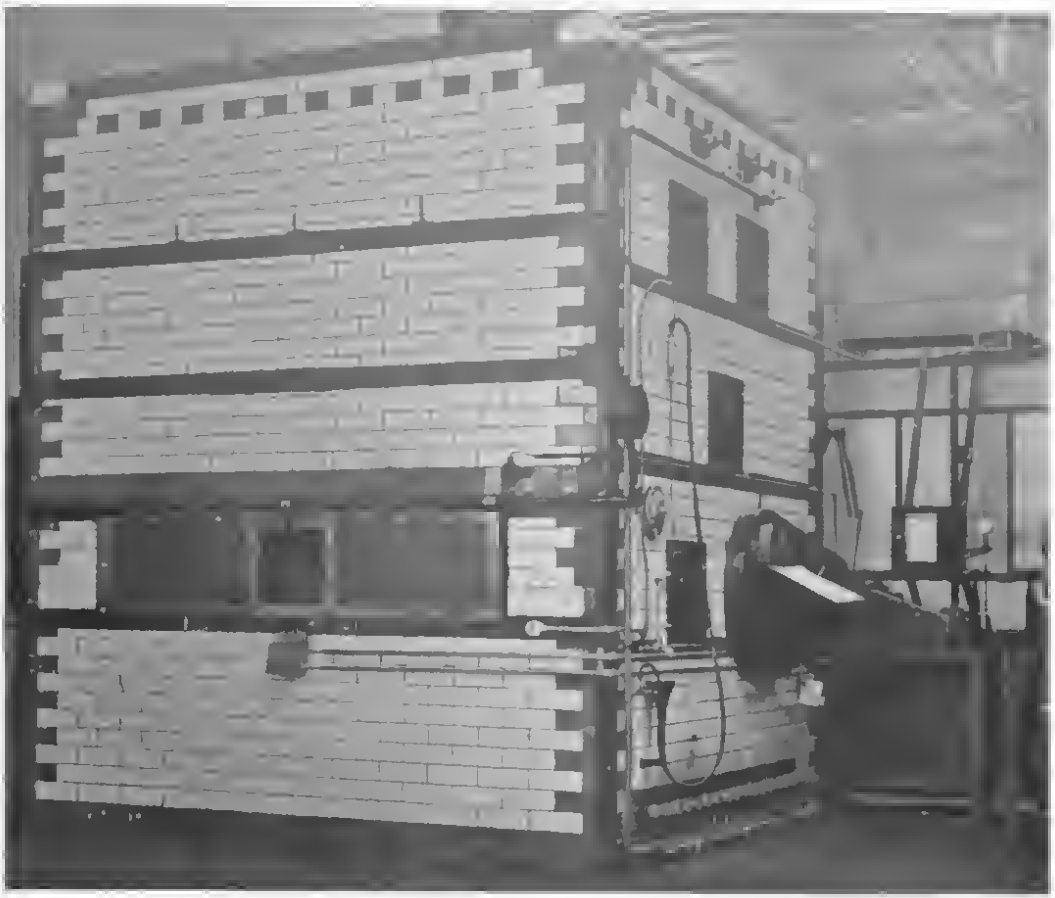

PLATE I. Photograph of a "rotating oven" showing the driving mechanism and the temperature recording device.

PLATE II. Photograph of another " rotating " or reel oven, the doors are open and the reel, with one pan, can be seen through the opening.

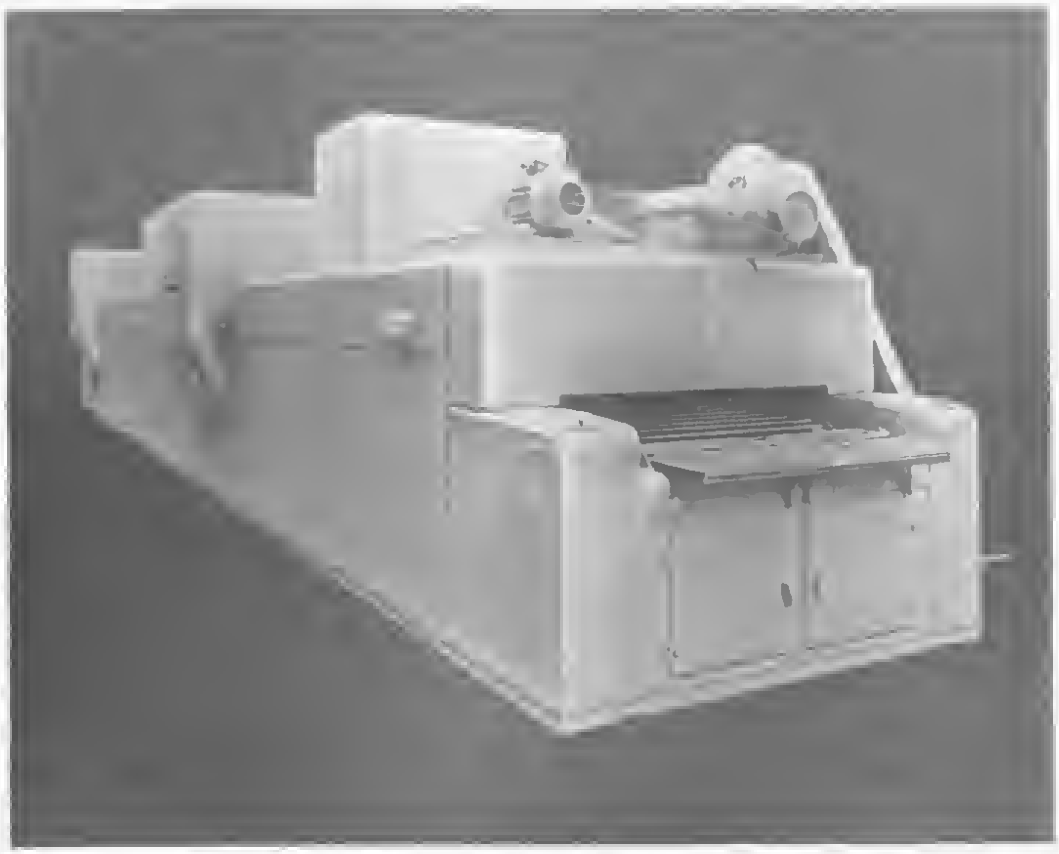

PLATE III. Photograph of a conveyor type oven, the "loading end" being at the front.

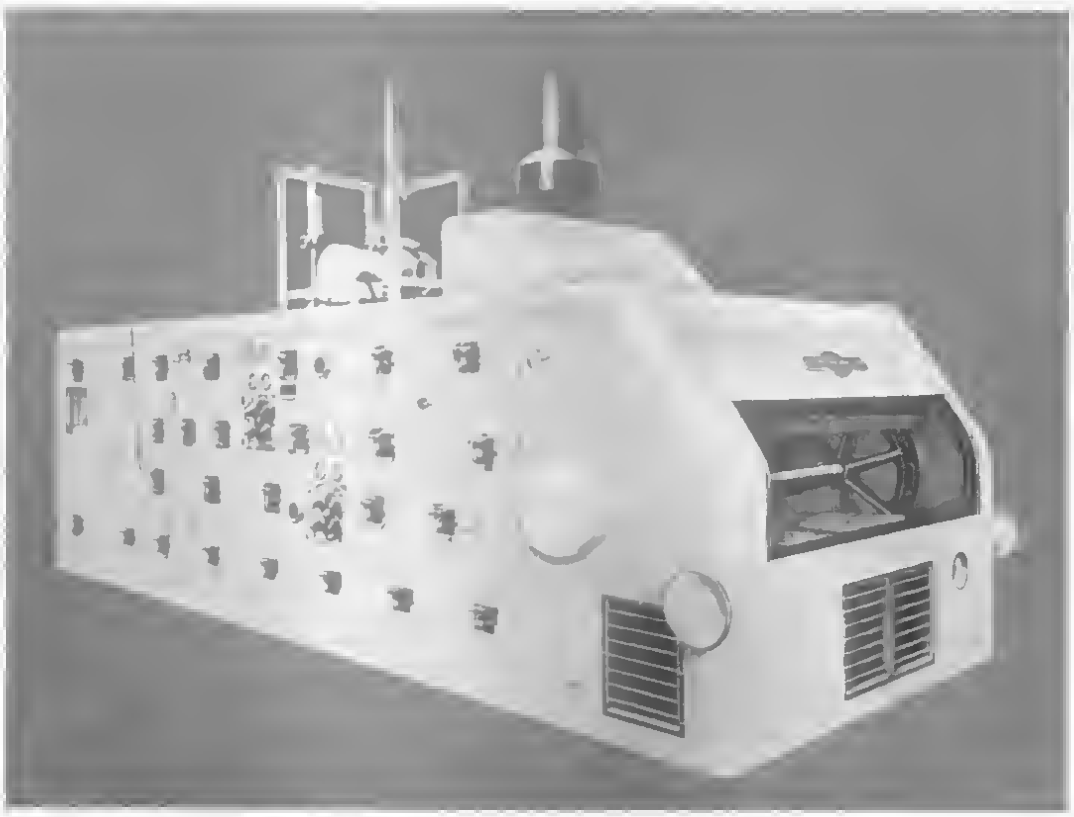

PLATE IV. Photograph of a travelling oven. The end door is open and two trays can be seen, the upper one is just commencing its travel round the oven and the lower one has been round and is ready for removal.